PACIFIC ISLANDS PROGRAM

University of Hawaii

Miscellaneous Work Papers

MICRONESIAN AND POLYNESIAN

VOYAGING

THREE READINGS

(1976: 1)

FOREWORD

In the fall of 1975 a course on Pacific voyaging was offered at the University of Hawaii under the instruction of Professor Ben Finney of the Anthropology Department. The focus was on Micronesian and Polynesian canoe voyaging. Interest in traditional voyaging was widely felt in Hawaii as the Polynesian Voyaging Society prepared to make an experimental round trip journey from Hawaii to Tahiti. The canoe Hokule'a was to make the voyage. That voyage has since been completed and attention will doubtless now be focused on the results of the experiments carried out in this venture. Some of the topics explored in the Hokule'a journey were uses of traditional navigation skills, canoe performance, diet, and transporting of plants and animals (Finney 1975:7). The students of the Pacific Voyaging course wrote research papers on topics related to the above.

This collection of papers from that course reflects the Hokule'a concerns. The work by Patricia Schattenburg on food and cultivar transportation deals with Micronesian voyaging, enabling the author to make use of research on traditional navigation which is still practiced in Micronesia. Patricia Beggerly's paper concerns a posited model of a Hawaiian initial settlement. The model details possible passengers and contents of the canoe first reaching Hawaii and examines the changes for survival of people, plants and animals enroute and once settled in Hawaii through use of several variables. Lesley Bruce has also written on Hawaii, researching the topic of Hawaiian knowledge of celestial navigation. This paper searches the works of Malo, Kamakau, and Kepelino for references to traditional astronomical and navigational knowledge. It is our hope that these papers will find an audience in the widespread interest in Pacific voyaging generated by the Hokule'a trip.

The Pacific Islands Studies program wishes to stimulate student efforts in research and so offers these as working papers. They are not finished products and should be regarded as initial endeavors in the study of Pacific voyaging. The aim is to share the information gathered by students, keeping in mind that this is a beginning and will pave the way for further work in several areas.

A note on format: These papers have been presented in the style of the journal American Anthropologist. References are found in the text in parentheses. The author's last name, year of publication of the work and page cited are given, e.g. (Suggs 1960:110). A list of references cited appears at the end of each paper. Only materials cited are presented, although other publications may have aided the author's background research. These citations are listed by author and subfiled by date. Title, place of publication and publisher are given for monographs; journal articles show title of the article, journal, volume and paging.

Co-editors: Karen Peacock, PIP Student,
Dr. Carl J. Daeufer, Acting Director,
Pacific Islands Program
Eng. Quad Bldg 31, Rm 1
University of Hawaii
Honolulu, Hawaii

Reference cited: Finney, Ben Rudolph. 1975 A Voyage into Hawaii's Past. Polynesian Voyaging Society News, (August).

MICRONESIAN AND POLYNESIAN

VOYAGING

THREE READINGS

PACIFIC ISLANDS STUDIES PROGRAM

University of Hawaii

(1976: 1)

Reading One

PRELIMINARY STUDY OF THREE POLYNESIAN SOURCES FOR CELESTIAL NAVIGATION

Lesley Bruce

> Factors which made possible the marvelous maritime exploits of the ancient Polynesians were: first, their skill in building staunch and seaworthy vessels; second, intensive study and cumulative knowledge disseminated in their schools concerning weather observation, winds, tides, ocean currents, geography, and astronomy; third, superb seamanship; and finally an unwavering faith in their gods.
>
> (Makemson 1941:32)

This is a study of what three native Hawaiian scholars say about celestial navigation. Makemson claims, in the passage above, that the marvelous ancient Polynesian maritime exploits were made possible because of skill, knowledge, and seamanship. The main problem considered in this paper is whether or not much is really known about Hawaiian navigational knowledge.

Few would disagree that deliberate canoe voyages to Hawaii from Central Polynesia were considered marvelous exploits, however some would prefer to describe them as "accidental" (Sharp 1956:149) and others discredit Polynesian navigational knowledge. Åkerblom concludes that "Polynesians...accomplished their voyages, not thanks to, but _in spite of_ their navigational methods" (1968:156 my emphasis). Similarly, Snow does not accept the idea of Polynesian navigational expertise because as he states,

> There is widespread and often uncritically accepted tradition that these people were expert navigators, but this is impossible because accurate navigation requires accurate measurements and precise timekeeping.
>
> (Snow 1970:11)

The problem of _how much_ Hawaiians knew about navigation might well be explored by an examination of early documents written by native Hawaiians. All Hawaiian sources I studied postdate European influence (1778) by 60 to 80 years, and although they vary in focus and the amount of information presented, the sources appear generally consistent. I think that this study will demonstrate that information on Hawaiian celestial navigation currently available represents a scant fragment of the original storehouse of data which must have been essential for inter-island Hawaiian and open-ocean Pacific voyaging.

The three primary sources investigated for information about Hawaiian navigation were:

1) The 1971 edition of David Malo's Hawaiian Antiquities which was written in the 1840's (Barrère/Personal Communication) and was first published in 1903.

2) Samuel Kamakau's Instructions in Ancient Hawaiian Astronomy as Taught by Kaneakahoowaha, one of the Counsellors of Kamehameha I was published originally in the Hawaiian newspaper Ka Nūpepa Kū'oko'a in 1865.[1] The English translation by W. D. Alexander[2] was published 26 years later in Thomas G. Thrum's 1891 Hawaiian Annual.

3) The 1971 edition of Kepelino's Traditions of Hawaii was written about 1868 (Barrère/Personal Communication) and first published in 1932.

In addition to these sources by native authors, a missionary volume, History of the Sandwich Islands, published in 1843 by the Rev. Sheldon Dibble was searched for information.

Among contemporary sources surveyed were Rodman (1927), Åkerblom (1968), Makemson (1938, 1939, 1941) and Lewis (1964, 1973).

It is worth noting that a thorough study of this subject should be undertaken only after one is knowledgeable in both astronomy and navigation; unfortunately, I lack a background in both. My study was further restricted by my limited ability to understand Hawaiian.

Translation of newspaper documents is beyond my current level of proficiency. Moreover, understanding the vision of the universe that Hawaiians had while working from the brief descriptions (Taylor 1965) available is not as simple as I had hoped. Thus the current report is only an account of what I found in about six weeks of sporatic search and in no way represents a definitive study.

The scope of this paper includes consideration of both primary and secondary sources mentioned above. In approaching these problems it is worth noting that navigation in Hawaii, as elsewhere in Polynesia, was traditionally subject to systems of belief and secret teaching (Snow 1970:11; Gladwin 1970:19-20; Lewis 1973:17). Most of the old systems in Polynesia have been lost. However, the work of Gladwin (1970) and Lewis (1973) has recorded and revived traditional techniques in Micronesia.

The many other techniques for navigating, besides astronomy, were not included in this study. Among these were determination of currents and swell, "sea marks" (Lewis 1964:365; 1973:249; Gladwin 1970:162-164), bird flight patterns (Weckler 1943:17-18), volcanic signs,[3] scents, clouds, island reflections, and flotsam and jetsam patterns (Makemson 1941:4; Weckler 1943:17; Sharp 1963:392).

Their exclusion is not meant to imply that any of these techniques were less important or necessary than using astronomical aids in voyaging, and it is important to stress that navigators combined all techniques and used them with sound judgement.

When one examines the primary sources on Hawaiian astronomy the problem of reliability of sources is immediately apparent. The manuscripts have often been processed through many hands. There may be inscribers, transcribers, translators and advisors. These people may have special biases which influence their choice of words. It is also highly likely that they may not have had a background in celestial navigation which qualifies them to deal with the subject.

Native Hawaiian scholars may have been influenced by American and European concepts. According to Dorothy Barrère (Personal Communication), Malo and Kamakau relied heavily on Hoapili for their astronomical information. Sahlins' article quotes William Richards as saying in 1841 "The late Hoapili...was accounted one of their most skillful astrologers." (Sahlins 1973:30). I am assuming in this context that astronomer and astrologer were synonomous. But one should be especially cautious of sources published after the informant, Hoapili, died.

I attempted to examine the first astronomy and geography textbooks which were published at Lahainaluna Seminary Press to see if they provided a clue to the exposure Malo and Kamakau may have had in these subjects. <u>Astronomy: that is, an explanation of the nature of the sun, the earth and the stars</u> (Clark 1837; Dibble 1909:417) came out in 1837. It may be the volume referred to by William Richards:

> The first little book which was published containing some of the true principles of astronomy awakened their surprise, and they at once brought forth the common vulgar objections to it.
>
> (Sahlins 1973:32)

A clue that the book referred to above must not have been the one I located comes in the subsequent passage that implies that

Hoapili examined the figure of the earth and was persuaded that the earth is round, for Hoapili said:

> When I have been far out at sea on fishing excurtions (sic), I always first lost sight of the beach—then the houses and trees—then the low mountains and last of all the high ones. So when I returned, I first saw the high mountains, then the lower ones, then the trees and houses, and last of all the beach. I think the foreigners are right, and that the earth is round.
>
> (Sahlins 1973:32)

But the astronomy book I located had no pictures. Geography books were illustrated; but a further search of astronomy texts needs to be made. A similar version of this story appears in Dibble (1843:110).

It is also worth mentioning in passing that the astronomy text reads more like the Old Testament creation stories in Genesis than like a science text of today. The fact that Lahainaluna was a Seminary to train Christian preachers is significant.

The story quoted above by Sahlins implies that Hawaiians were willing to shift their view of the world in accordance with the new information.

In shifting from early textbooks to the men for whom they were written, let us look at the works of David Malo, Samuel Kamakau and Kepelino. David Malo was born about 1793, fifteen years after the arrival of Captain Cook and died in 1853 at about the age of sixty. His life spanned from the arrival of the missionaries to the heyday of the whaling period. He lived in Lahaina, and later had two churches where he was the preacher; one in Kalepolepo (near Kihei) and the other in Keokea, (Kula) Maui.

In 1831, when Lahainaluna was founded, he was one of the first pupils to enter; at that time he was thirty-eight years old. He worked for Sheldon Dibble collecting history and folklore and is supposed to be one of the main contributors to History of the Sandwich Islands (1843). Perhaps Malo supplied the information about Hoapili which appears identically in both Dibble (1843:110) and Richards (Sahlins 1973:32)

But what can be found about celestial navigation in Malo's writings? One of his books, a Life of Kamehameha I (Malo 1971:xviii) was lost. His Hawaiian Antiquities (1971) contains virtually nothing about the subject. A chapter on the compass (p. 9-12) and "Terms used to designate space above and below" (p. 12-16) give some sense of the Hawaiian conception of the universe, and "The Hawaiian canoe" (p.126-135) provides names of parts and some chants; but I could find nothing in Malo on navigation.

Edwin H. Bryan, Jr., Director of the Pacific Scientific Information Center at the Bishop Museum and former teacher of astronomy at the University of Hawaii, has indicated (Personal Communication) to me that Malo never gives any specific data on anything of a scientific nature.

Thus, I have dismissed Malo in my search for information from natives on Hawaiian celestial navigation. The next author considered was Samuel Manaiakalani Kamakau (1815-1876) who, according to Rubellite Johnson (Personal Communication) of the University of Hawaii, is the best native source on the subject of navigation. Others have also praised Kamakau. Edwin H. Bryan pointed out that while Kamakau doesn't say much about technical astronomy, he may have known something about navigation.

Kamakau was well qualified as an historian. Thomas Thrum, reflecting the feeling that prevailed both during Kamakau's life and after he died, praises the latter's knowledge of both history and traditions. He quotes an Advertiser editorial of March 31, 1866:

> In ancient traditional knowledge of the Hawaiians the late David Malo alone excelled him. (Kamakau)
> (Thrum 1918:48)

Thrum also quotes Judge Abraham Fornander as saying that "Probably the best informed Hawaiian archaeologist of the present day is S. M. Kamakau, but even he is often very credulous, inconsistent and uncritical" (Thrum 1918:45). Another more favorable appraisal was made by Thrum himself:

> As a (sic) historian and legendary writer he stood peerless and alone among the present sons of Hawaii. He was a man who might well be called a representative Hawaiian. There are but few today who present as he did the characteristics of Hawaiians, unhurt by the various influences of civilization. As a thinker and reasoner, he was thoroughly original; he looked at questions of the day from a position so peculiar as to be accountable for them only on the theory of his inbred Hawaiianism. His memory was remarkably accurate and acute...
> (Thrum 1918:52)

What was the background of one so highly praised as Kamakau? He was born in Mokuleia, Waialua, Oahu, in 1815 and at the age of 18, in 1833, enrolled at Lahainaluna where he was one of a class of 24 students. He stayed there seven years as a pupil and teacher's assistant, starting his research on historic writing in 1836 and continuing until 1848 (Thrum 1918:45). After this time he became a member of an association whose purpose was the "conservation of historical data" (Thrum 1918:41). Thrum says this historical society, formed in 1841, was set up to study the

> ...origin of this race and to obliterate the common belief among some foreigners who claim that this is a wandering race which was lost in a storm and driven by the winds to these shores.
>
> (Thrum 1918:41)

In the course of this historical work, Kamakau "materially aided" (Thrum 1918:40) Fornander both in the compilation of the Collection of Folklore and Polynesian Race. These documents were not used in this present study because of the shortness of time and their emphasis on traditional lore which is outside the scope of this study.

After his time at Lahainaluna, and until his death (1876) in about his sixtieth year, Kamakau published in newspapers. In one of these articles we find the most important document on Hawaiian astronomy, Instructions in Ancient Hawaiian Astronomy as taught by Kaneakahoowaha, one of the Counsellors of Kamehameha I. This work is available both in original newpapers (Ka Nūpepa Kū'oko'a August 5, 1865) and in an English translation by W. D. Alexander published by Thrum in 1891 (Hawaiian Annual 1891:142-43).

This article begins by describing a gourd which illustrates and vividly conceptualizes astronomical ideas. The ideas postdate European influence (Cook - 1778) by 87 years and missionary influence (1820) by 45 years. Kamakau describes a gourd on which lines are drawn to represent the highways of the navigation stars, outside

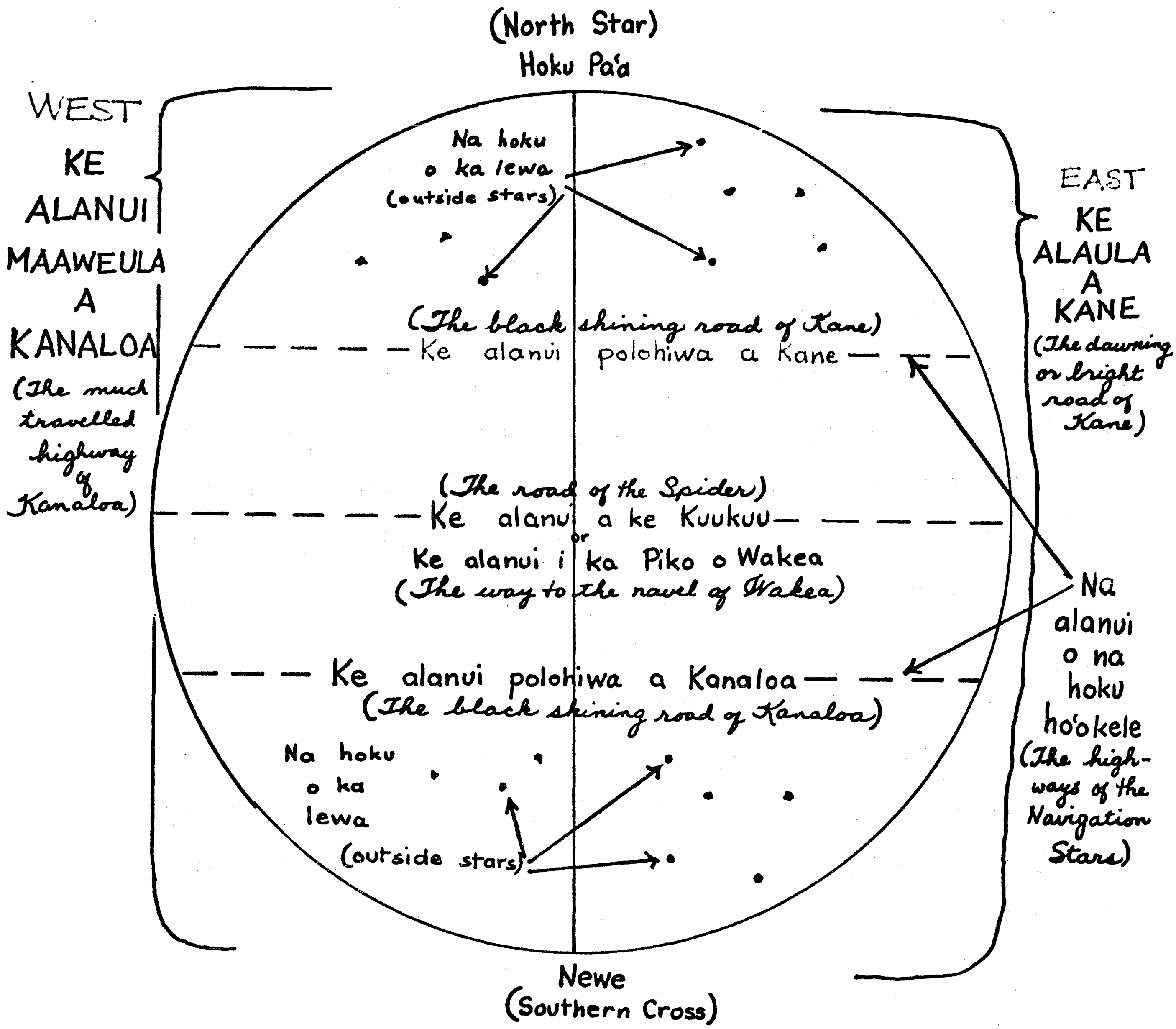


DIAGRAM OF GOURD DESCRIBED BY KAMAKAU (1865:142)

Figure 1

stars, the north star and the southern cross. Two lines define the parameters of the apparent motion of the sun from north to south and a third marks "the way to the navel of Wakea" which marks the celestial equator or the position of the sun during the equinoxes (Kamakau 1891:142). (See Figure 1)

There is no way to verify whether these concepts are based on European ideas and simply assigned Hawaiian names, or whether the Hawaiians had these concepts as part of their astronomical knowledge. Mr. Bryan of the Bishop Museum suspects that the Hawaiians were well aware of the limits of the sun's variability in moving from north to south and, I might add, the midpoint of the sun's path may have been determined to help establish the variability on either side.

The purpose of calling stars beyond these north and south limits "outside stars" (Nā Hōkū o ka lewa) is not clear with regard to how they relate to navigation. Moreover, why these north and south limits of the sun's movement are labelled the "highways of the navigation stars" (Nā alanui o nā hoku ho'okele) is also not clear.

The information on horizon stars and zenith stars that I was hoping and expecting to find is nowhere present in this article. Clues about how to use swell, birds, currents, and other presumably necessary navigational aids are not included either. By the absence of these details one must conclude that only a scant fragment of the knowledge necessary to navigate in Hawaiian waters or over the Pacific remained in the time of Kamakau.

The reason this may be so is related to the fact that the

Hawaiians had given up voyaging to the south about 500 years before Kamakau's time. It is not hard to conceive how easily the ideas might be lost since navigation was a skill which required constant practice and the knowledge about it was conveyed only to a few people.

In concluding this section on Kamakau, it is worth noting that he made a deliberate attempt to relate the Hawaiian concepts to the new ideas which the missionaries introduced. In fact, in his book, The Works of the People of Old (Nā Hana a ka Po'e Kahiko)(In Press), after a discussion of the Hawaiian concepts of horizons, he says

> We of today can compare these terms with those used now and see how much alike they are.
> (Kamakau In Press:6)

Thus his tendency to see likenesses might have heavily skewed the information Kamakau was reporting on.

When one moves to Kepelino, one is faced with problems that are similar to the problem of searching for information in Malo's works. Kepelino does deal with related subjects: calendar (1971:84-97), seasons (1971:82-85), and star lore (1971:78-83). But the latter subject is treated with the greatest brevity.

But before looking at the information he offers, Kepelino's background needs to be examined. He was also known as "Kahoali'-ikumaiwakamoku" ("To be the chief of the nine districts"), "Kepelino Keauokalani", "Zepherine", and "Zeperino". He was born on the island of Hawaii around 1830 and died about 45 or 50 years later in about 1878 (Kepelino 1971:4-5). His birthdate postdates by about a decade the arrival (1820) of Calvinist missionaries from Boston. His parents were among the earliest converts to the Catholic mission which was established in Kailua, Kona, in 1840[4] when Kepelino was about 10 years old.

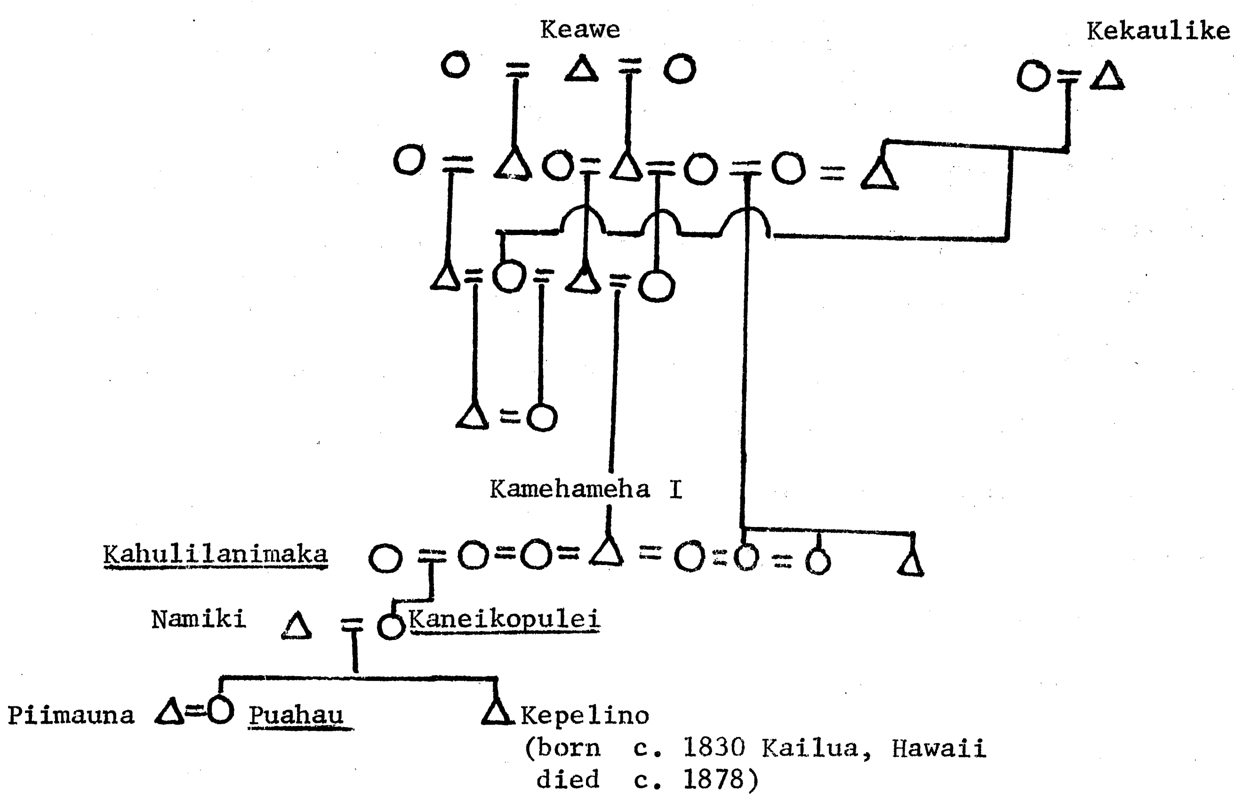
What education and background did Kepelino have that might qualify him as a native source of celestial navigational knowledge? He did not attend Lahainaluna Seminary as Malo and Kamakau did. Rather, he studied English, French, Latin and Greek with Bishop Maigret at the Catholic High School at Ahuimanu. I have found no direct or indirect evidence concerning the kinds of books used by the Catholics in their education of Hawaiians. However, since the purpose of this education was primarily for religious conversion and teacher training, one might assume that scientific knowledge played a minor role in the total curriculum.

If he did not learn much about navigation from books, in what other ways might Kepelino have learned? It is worth noting that he had the opportunity to sail to Tahiti in 1847 on a voyage of 31 days (Beckwith In Kepelino 1971:4). But one would presume that the voyage was accomplished by European navigational techniques. What Kepelino would have gained from it would have been general information about the voyaging of his time, and virtually nothing about traditional canoe navigation.

One might also ask in examining Kepelino's credentials as a source of native voyaging information: what might he have learned from his family? In this regard, it is important to note that he traced his paternal ancestors back to Pa'ao (Beckwith In Kepelino:

1971:5) who, according to traditions, sailed from Tahiti to Hawaii a couple of times (Emerson 1893:5; Buck 1964:283; Finney 1967:163; Malo 1971:6) and "may have helped to establish the system of sailing directions for this route" (Bryan 1955:45). Pa'ao was renowned as "a skilled navigator...adept in the astronomical lore of the time" (Emerson 1893:12), but the number of generations intervening between Pa'ao and Kepelino is not known and because Pa'ao is essentially a legendary figure[5], this is a tenous link to astronomical knowledge.

Since I was unable to locate the paternal geneology of Kepelino, I explored his mother's side. (See Figure 2) Kepelino's mother,



*females underlined

Figure 2

Kaneikopulei, was a daughter of Kamehameha I and Kahulilanimaka. One might assume that this high chiefly line would have access to navigational knowledge, but one can easily question whether such knowledge was being passed on after the introduction of European sailing vessels[6] (1790's) and the intensive missionary effort to convert natives to Christianity (after 1820). The information I had access to stressed his education by a French Catholic priest and made no mention as to whether or not members of his family were passing on their traditions to him. Moreover, I found nothing to indicate that Kepelino was particularly interested in celestial navigation.

In Kepelino's only published work, Traditions of Hawaii, nineteen out of eighty pages (1971:74-113) deal with "Star lore and the calendar." Most of these pages concentrate on the calendar. However, one sentence has been the focus of a discussion by Makemson, Åkerblom (1968:39-40), and Lewis (1973:238). The problem, as Lewis defines it, is whether a zenith star concept is suggested by this sentence:

> 'Oia nā hōkū e kau pākāhi ana maluna iho o kēlā 'āina keia 'āina, e like me nā hōkū-le'a ma ko Hawai'i nei pae-'āina, a me nā hōkū-ke'a ma nā mokupuni o Tahiti, &. &. (Kepelino 1971:83)

The translations by Beckwith and Elbert demonstrate a difference in that one suggests a horizon star concept (kau = rise) and the other interprets the same word as a possible zenith star concept (kau = suspended over)

GUIDING STARS	PROTECTING STARS
The stars that act as guides	These are the stars that are
to land are those that rise	suspended severally
over each land,	over the various lands,
like the Hoku-Lea that	such as Hoku-lea in the
rises over the Hawaiian islands	Hawaiian Islands
and the Southern Cross	and the Southern Cross
over the Tahitian, and so forth	over the lands of Tahiti, etc.
(Beckwith In Kepelino 1971:82)	(Elbert In letter to Finney 1969:n.p.)

After showing the differences between Beckwith's translation (stars "that rise (kau) over each land"; (Beckwith In Kepelino 1971:82) and Mäkemson's and Elbert's version (stars "that are suspended (kau) severally over the various lands"; (Makemson 1941:13 and Samuel H. Elbert's letter to Ben Finney 11/19/69 cited in Lewis 1973:238), Lewis points out the European influence in Kepelino's use of the term "Tahiti" instead of the traditional Hawaiian term Kahiki, implying the zenith concept is a European interpolation. It may well be, but this raises a problem Lewis does not discuss. Perhaps Kepelino actually means Tahiti in this context, for there is no necessary one-to-one correspondance between Kahiki and Tahiti in the Hawaiian language. Andrews, in his dictionary published originally in 1865, gives the meaning of Kahiki as

> The general name of any foreign country
>
> (Andrews (1865) 1974:244)

while Pukui and Elbert, in a more recent dictionary, say it means

Any foreign country, Tahiti

(Pukui and Elbert 1971:104)

Thus, it may be that Kepelino was referring directly to Tahiti, the place he had visited as a youth.

One must conclude that one cannot readily assume that Kepelino's "Guiding Stars" (1971:82-83) section is describing zenith stars. Åkerblom expresses the currently prevailing view that the concept is part of a putative system, for as he claims

> ...there is nothing to suggest that the Polynesians did in fact fix their latitude by observing a zenith star.
>
> (Åkerblom 1968:38)

The process of manuscript handling is a particular problem in the case of Kepelino. Apparently he dictated the material to Bishop Maigret, the founder of the Catholic mission, who recorded it, presumably in Hawaiian. (I have not seen the original document.) This manuscript was then typed by Father Reginald Yzendoorn, the Catholic mission's Chancellor-Secretary, in 1931. This typescript was translated by Mary Kawena Pukui and Martha Beckwith with advice from Lahilahi Webb and John Wise. Chants were checked by Mrs. Pukui's mother, Mrs. Wiggin. Then the book was published by the Bishop Museum. Seven people worked over Kepelino's spoken words. How much was lost or added in the handling is a matter for speculation.

In concluding this section on Kepelino, it should be reiterated that his writings are not especially helpful to the study of Hawaiian astronomical knowledge. While his information on the names of stars and the calendar might be useful to those making comparative studies, they do not add new information to what is offered elsewhere by others.

In conclusion, I would like to return to my original thesis that only a small fragment of Hawaiian astronomical knowledge remains. We do know lists of star and planet names, names of the seasons, months and days. But these are like three darts on a well-used dart board; they are what we see now. The holes that marked where many other darts hit represent the many things that were once there but are now gone. No visible traces remain of Hawaiian astronomical knowledge, because of its very nature as an art based on verbally transmitted knowledge conveyed to very few experts, and because so much of the actual navigation was done on the basis of expert judgement. How could one expect such knowledge to last five centuries with an absence of open ocean voyaging? For when Europeans came to the Hawaiian Islands in 1778, voyaging was limited to inter-island canoe trips. Professor Kyselka, of the University of Hawaii, with whom I agree, points out the limitations of knowledge of Hawaiian navigational methods:

> We know little of the ancient methods of navigation. The men that Captain Cook talked with were many generations removed from those who made the long voyages, but they were skilled/in the ways of the sea, and traveled between the islands guided only by the stars.
>
> (Kyselka 1969:n.p.)

NOTES

1 Ka Nūpepa Kū'oko'a, "No ke a'o hoku" Ke kilohana Po'okela no ka Lahui o Hawai'i. Buke IV Helu 31. Honolulu, Augute 5, 1965, Na Helu a pau 192. 4th page.

2 William DeWitt Alexandar (1833-1913).

3 No sound data reflecting distances at which volcanic eruptions and resultant metereological disturbances are visible at sea were found in this study. Furthermore, as far as I know, no one has tried to correlate early archaeological sites with eruptions; thus Makemson's statement:

> The original discoverer of the Hawaiian group was undoubtedly aided by seeing the reflection of volcanic fires on the clouds, which must have been visible at night from a great distance.
>
> (Makemson 1941:12)

can only be considered highly speculative.

4 The first Catholic missionaries came to Hawaii on July 8, 1827; the Kona mission was established in the 1840's by French priests of the Congregation of the Most Sacred Hearts of Jesus and Mary. (Monsignor Marzen, Hawaii Catholic Herald, Personal Communication)

5 Dr. Ben R. Finney has pointed out that while the Pa'ao legends (1967:163-164) need not be taken as literal history, it can't be "...ignore (d) that two-way voyaging was a common feature in Hawaiian traditions of the Tahitian contact era." (1967:164)

6 Vancouver left some of his shipwrights to teach the Hawaiians to build their own vessels. In 1794 the first vessel was completed. (Marion A. Kelly, Bishop Museum, Personal Communication)

REFERENCES CITED

Åkerblom, Kjell
1968 Astronomy and Navigation in Polynesia and Micronesia: A Survey. Stockholm: Ethnographical Museum.
Andrews, Lorrin
1974 A Dictionary of the Hawaiian Language, To Which is Appended an English-Hawaiian Vocabulary and a Chronological Table of Remarkable Events. Rutland, Vt.: Charles E. Tuttle Company. First published: 1865.
Anonymous
1882 Hawaiian Ideas of Astronomy, Compiled from Dibble's History of the Sandwich Islands 1843. In Hawaiian Almanac and Annual for 1882. Vol. 8. Thomas G. Thrum, Ed. Honolulu: Robert Grieve Printer. pp. 49-50.
Barrère, Dorothy
1975 Personal Communication.
Boulinier, Georges and Geneviève Boulinier
1972 Les Polynesiéns et la Navigation Astronomique. Journal de la Société des Océanistes 28: 275-284.
Bryan, Edwin Horace
1955 Stars Over Hawaii. Honolulu: Books About Hawaii.
1962 Astronomy in Hawaii. Unpublished Paper Presented at the 14th Annual Convention of Western Amateur Astronomers. Aug. 23, 1962. Xerox Copy, Pacific Science Information Center, Bishop Museum.
1965 Astronomy and the Calendar. In Ancient Hawaiian Civilization. E.S. Craighill Handy et al. Rutland, Vermont: Charles E. Tuttle Co. pp.251-256.
Clark, Ephraim Weston
1837 O ke Aohoku: oia ka mea e Akaka'e ke Ano o ka La a me ka Honua, a me na hoku (Astronomy: That is an Explanation of the Nature of the Sun and the Earth and the Stars). Lahainaluna: Press of the Mission Seminary.
Dibble, Sheldon
1843 History of the Sandwich Islands. Lahainaluna: Press of the Mission Seminary.
1909 A History of the Sandwich Islands. Honolulu: Thrum.
Dodd, Edward Howard
1972 Polynesian Seafaring; a Disquisition on Prehistoric Celestial Navigation and the Nature of Seagoing Double Canoes... The Ring of Fire, Vol. 2. New York: Dodd, Mead and Co.
Elbert, Samuel H.
1969 Unpublished letter to Ben Finney. November 19, 1969.
Emerson, Nathaniel Bright
1893 The Long Voyages of the Ancient Hawaiians. Paper 5. Honolulu: Hawaiian Historical Society.
Emory, Kenneth Pike
1965 Navigation. In Ancient Hawaiian Civilization. E.S. Craighill Handy et al. Rutland, Vermont: Charles E. Tuttle Co. pp. 241-250.

Finney, Ben Rudolph
1967 New Perspectives on Polynesian Voyaging. In Polynesian Culture History. Genevieve A. Highland et al., Eds. Special Publication 6. Honolulu: B.P. Bishop Museum. pp. 141-166.
1975 A Voyage into Hawaii's Past. Polynesian Voyaging Society News.
Fornander, Abraham
1878 An Account of the Polynesian Race. Vol. 1. London: Trübner.
Gladwin, Thomas
1970 East is a Big Bird: Navigation and Logic on Puluwat Atoll. Cambridge: Harvard University Press.
Golson, Jack, Ed.
1972 Polynesian Navigation: A Symposium on Andrew Sharp's Theory of Accidental Voyages. Wellington: A.H. and A.W. Reed.
Hilder, Brett
1969 The Magic of Polynesian Navigation is Now Legend. Pacific Islands Monthly.
Holmes, Lowell D.
1955 The Polynesian Navigators Followed a Unique Plan. Pacific Island Monthly.
Johnson, Rubellite
1975 Personal Communication.
Kamakau, Samuel M.
1865 Na ke ao hoku (Concerning the Stars). Honolulu: Ka Nūpepa Kū'oko'a, August 5.
1891 Instructions in Ancient Hawaiian Astronomy as Taught by Kaneakahoowaha, One of the Counsellors of Kamehameha I. Translated from Ka Nūpepa Kū'oko'a, August 5, 1865, by W.D. Alexander for the Maile Wreath. Hawaiian Annual. Honolulu: Thrum. pp. 142-143.
1961 Ruling Chiefs of Hawaii. Honolulu: Kamehameha Schools Press.
In Press The Works of the People of Old: na hana a ka po'e kahiko. Translated from the newspaper Ke Au 'Oko'a by Mary Kawena Pukui. Arranged and edited by Dorothy B. Barrère. Special Publication 61. Honolulu: B.P. Bishop Museum.
Kelly, Marion A.
1975 Personal Communication.
Kepelino
1971 Traditions of Hawaii. Martha W. Beckwith, Ed. Reprint. Bulletin 95. Honolulu: B.P. Bishop Museum.
Kupahu
1865 Hoomana Kahiko (Ancient Authority). Honolulu: Ka Nūpepa Kū'oko'a. December 30, 1865.
Kyselka, Will
1971 The Hawaiian Sky. Honolulu: Pacific Books - Hawaii.
_____ and George Bunden.
1969 Polynesian Stars and Men. Honolulu: Bishop Museum Science Center.
Lewis, David
1964 Polynesian Navigational Methods. Journal of the Polynesian Society 73: 364-373.
1973 We, the Navigators: the Ancient Art of Land Finding in the Pacific. Honolulu: The University Press of Hawaii.

Makemson, Maud W.
1938 Hawaiian Astronomical Concepts I. American Anthropologist 40: 370-383.
1939 Hawaiian Astronomical Concepts II. American Anthropologist 41: 589-596.
1941 The Morning Star Rises: An Account of Polynesian Astronomy. New Haven: Yale University Press. Xerox.
Malo, David
1971 Hawaiian Antiquities (Ko'olelo Hawai'i). 2nd ed. Special Publication 2. Honolulu: B.P. Bishop Museum.
Marzen, Monsignor
1975 Personal Communication.
Pukui, Mary Kawena and Samuel H. Elbert
1971 Hawaiian Dictionary. Honolulu: University of Hawaii Press.
Rodman, Hugh
1927 The Sacred Calabash. Proceedings, August 1927. Anapolis, Md.: U.S. Naval Institute.
Sahlins, Marshall and Dorothy Barrère, Eds.
1973 William Richards on Hawaiian Culture and Political Conditions of the Islands in 1841. The Hawaiian Journal of History 7: 18-40.
Sharp, Andrew
1956 Ancient Voyagers in the Pacific. Memoir 32. Wellington, N.Z.: Polynesian Society.
1963 Polynesian Navigation: Some Comments. Journal of the Polynesian Society 72: 392.
Snow, Dan
1970 Ancient Skills in Navigation. Explorer 12: 11-12.
Taylor, Clarice B.
1965 Hawaiian Almanac. Honolulu: Tongg Publishing Co., Ltd. Chart of the Universe, p.4.
Te Rangi Hiroa (Peter H. Buck)
1955 Sir Peter Buck Rejected Magic Calabash. Pacific Islands Monthly.
1964 Arts and Crafts of Hawaii: Section VI: Canoes. Special Publication 45. Honolulu: B.P. Bishop Musuem.
Thrum, Thomas George
1918 Brief Sketch of the Life and Labors of S.M. Kamakau, Hawaiian Historian. Twenty-Sixth Annual Report, 1917. Honolulu: Hawaiian Historical Society. pp. 40-61.
Valier, Louis A.
1962 Polynesian Navigation. Unpublished paper present at the 14th Annual Convention of Western Amateur Astronomers. Aug. 23, 1962. Xerox copy, Pacific Science Information Center, Bishop Museum.
Weckler, Joseph Edwin
1943 Polynesians: Explorers of the Pacific. War Background Studies 6. Washington, D.C.: Smithsonian Institution.

Reading Two

FOOD AND CULTIVAR PRESERVATION IN MICRONESIAN VOYAGING

Patricia Schattenburg

TABLE OF CONTENTS

INTRODUCTION

This paper will attempt to deal with the problem of food transportation and preservation in Micronesian voyaging and also with the problem of transportation of cultivars (Defined as "an organism of a kind [as a variety, strain, or race] that has originated and persisted under cultivation." Webster's Third New International Dictionary) The Polynesian outlier Kapingamarangi is included in this survey as it is in the same general geographic area.

Proto-Micronesians migrated into the Marshalls, Gilberts, Carolines and Marianas, successfully island hopping and eventually covering an area of over 4,000 square miles. They brought food and cultivars with them. Today, even though modern shipping operates throughout Micronesia, voyaging by natives in native craft is still taking place (Gladwin 1970). In discussing today's Micronesian voyaging, it would not be difficult to imagine that today's methods of food preservation and cultivar transportation are similar to past practices, discounting, or course, any modern technological methods that have crept into use. (In my reading I found mention of metal coconut graters made by nail holes punched in sheets of tin. I found no mention of refrigeration or preservatives in any of the descriptions of food preparations.)

It is immediately apparent that there is little written on the subject of provisioning for voyages in pre-contact days. A contemporary and very useful source for this paper was Some Tropical South Pacific Foods, by Murai, Ben and Miller, (1958). Carey D. Miller was the head of the Foods and Nutrition Department for the Hawaiian Agriculture Experiment Station and was the senior authoress of the book, and thus I will refer to Miller (1958) throughout this paper. The book discusses food preparation and preservation and nutrative values in the islands of Micronesia, specifically the Marshalls and Carolines. For information on the Gilberts I relied on Arthur Grimble's "Migrations of a Pandanus People" which appeared as memoirs in a supplement to the Journal of the Polynesian Society, (1933). Further sources were Sir Peter Buck's Material Culture of Kapinga-marangi, (1950). I often referred to Gladwin (1970) in order to get a general feel and picture of Micronesian voyaging. Mr. Donald Anderson of the Lyon Arboretum graciously spent a morning with me describing his canoe voyages in Fiji, the Tuamotus and Central Carolines. This was the only material that I could find on the transportation of cultivars. I attended the Kualoa Workshop in October, 1975 and heard lectures by Paige Barber and June Gutmanis, two of the women who are preparing food for the Polynesian Voyaging Society voyage.

Micronesian voyaging is like island hopping when compared to the Hawaiian-Tahitian migrations. Micronesia is an area with both low and high volcanic islands and atolls. According to Gladwin's experience, trips of several hundreds of miles have been undertaken, although the trips are usually shorter than that. In either case rarely were the voyagers out of sight of land for any significant length of time. Thus, food preservation and transportation of cultivars does not become a critical factor.

Micronesian weather is seasonal and subject to hurricanes and typhoons. Thus, there are periods of plenty and periods of want. Preservation of food becomes a necessity of everyday life. As with many other primitive peoples, the Micronesians had a diet limited to a few foods. Through generations they worked out a diet of food which their islands could support. That their diet was adequate is indicated by the comments of the early explorers concerning their good teeth and physical condition. Buck (1950) believed that when the people of Kapingamarangi cultivated and ate their own food their nutrition and their vitality was better than those who ate "civilized food". Some nutritional deficiencies were found by the Alpert Report (1940), but Miller (1958:2) feels that this is due to interrupted native diet due to the war and several generations of Western and Oriental influence.

In reviewing the literature it becomes apparent that the Micronesian diet consists primarily of breadfruit, coconut, *Cyrtosperma* and pandanus. Other less eaten foods such as banana, *apuch* (*Crataeva speciosa*) and arrowroot will not be considered here.

BREADFRUIT

Breadfruit is one of the basic foods of the natives of many tropical islands and in the Marshalls and Carolines it is preferred to the starchy aroids. It has played such a role in their lives that many Pacific ethnic groups have accounts of the creation of breadfruit in their folklore.

The breadfruit species is native to Malaysia and belongs to the Moraceae family. The same family contains the figs and banyans, although they are of different genera. Breadfruit offers a variety of ethnobotanical uses to the Micronesian, but our interest here is in its food uses and values. There are varieties of breadfruit within the species Artocarpus altilis. Some have small seeds, some large and some are seedless. Breadfruit has less tolerance to salt soil than does pandanus or coconut. Miller (1958:9) states that the distribution of productive breadfruit closely follows the pattern of salinity in the ground water. Miller (1958:9) also states that in a personal interview, Dr. Kenneth Emory said that the seeded variety is hardier and will grow better on a coral atoll. Dr. Emory believes that "the seeded breadfruit is a more valuable timber tree as it attains a far greater height", with a straighter trunk.

Breadfruit was named by William Dampier who first saw it on Guam in 1686 and wrote that, "The breadfruit (as we call it) grows on a large tree, as big as our largest apple trees... There is neither seed nor stone in the inside but all is of a pure substance like bread."

In the seeded varieties the seeds are also cooked and taste like chestnuts. The seedless varieties are eaten only in the cooked state. The seeded varieties can be eaten without cooking.

The length of the breadfruit season is influenced by the location and latitude and type of island (volcanic or atoll), the part of the island and the variety grown. However, in general it could be said that the season begins in May, peaks in August and ends in December. In the southernmost islands of Micronesia the season lasts more or less all year long. Starchy aroids and pandanus flour are used in between.

Miller (1958:15-17) refers to native names of methods of cooking ripe and green breadfruit in some detail. One method used by the Trukese is of interest. Cooked mature breadfruit is scraped and pounded and made into _kon_ by the men. They pound the breadfruit on a board with a pounder made of coral rock, the shape being very similar to Hawaiian poi pounders. The men pound enough _kon_ to make a loaf weighing 8 or 10 pounds. The loaves are made into meat bundles by binding them with breadfruit, banana or _taro_ leaves. _Kon_ may be eaten the day it is made or it may be stored. By the fifth or sixth day it begins to ferment and can still be eaten, although it is preferred fresh.

During the breadfruit season _kon_ is the most important food of the Trukese. Men and women carry it in bundles on their heads as they walk along the roads. In Truk, food is not given to travelers unless they are of the same clan, so they must take their own food as they travel about. According to Miller (1958:16) the Trukese also take leaf wrapped packages of _kon_ on their native boats.

Preserved breadfruit in the Marshall Islands is called _bwiru_. The following description from Miller (1958:18) is extracted from Dr. Leonard Mason's field notes taken in 1950. The uncooked mature breadfruits are scraped with a shell scraper. The fruits are cut in two lengthwise and the cores are removed and discarded. Batches of the cut fruit are placed in sennit nets and immersed in salt water in the lagoon or the ocean side. The bags are anchored with a piece of coral to keep them from floating away. They are left there for a day and a night. The fruit is then taken from the water, piled on the ground and covered with palm fronds. It remains there for two days and two nights until it becomes very strong smelling and soft. The breadfruit is squeezed between the fingers to make a doughy mass. This mass is sprinkled with fresh water and stirred once a day for 3 days. It is now called bwiru. The bwiru is placed in a pit lined with dried breadfruit leaves and palm fronds and left for about 2 weeks before using. By changing the leaves daily and later weekly, the bwiru can be kept for as long as two years. The bwiru is removed from the pit as needed and is washed and cooked before using.

Several dishes are made by the Marshallese out of the bwiru. In the preparation of manakajen the bwiru is taken from the pit and compressed on coconut fiber in slabs and left in the sun to dry. In appearance it is gray-white and resembles slabs of clay. In a week it becomes very hard. In this form it will keep indefinitely, thus forming an excellent emergency food. In order to keep it clean and insect free it is wrapped in plaited pandanus bundles and stored. Miller (1958:32) states that a slab of manakajen was loosely wrapped in a piece of waxed paper and stored on a laboratory shelf for three years without any signs of deterioration. Manakajen can be reconstituted by being broken into small pieces and soaked in water overnight. It is washed in several changes of water and drained. Then it is kneaded on a board until it becomes a sticky mass and is used to make Marshallese dishes of ieok, chubwe and bitro, the recipes for which are listed in Miller (1958:21). These dishes are immediately perishable. For this paper we will restrict our discussion to recipes of preserved breadfruit.

In the Carolines a preserved breadfruit is made called apot. The mature breadfruits are scraped and left on the ground overnight covered with banana leaves. A pit 2 feet by 5 feet square and 2 feet deep is dug in the earth and lined with 3 or 4 layers of banana leaves. In the pit are placed several hundred breadfruit and they are covered with leaves and weighted down with rocks. When the pit is opened 2 or 3 months later the breadfruit is an homogeneous mass of fermentation with a strong odor. The mass may be left in the pit for as long as a year with the needed portions being removed from time to time.

From the apot the Carolines people make apot mei mon and apot mei pupu which are immediately edible. It is not reported that the Carolines people make an intermediate stage of dried breadfruit as the Marshalles do with their manakajen.

In Material Culture of Kapingamarangi, Buck (1950:36) gives a detailed description of the preparation of preserved breadfruit or pakukura. The women peel the green mature breadfruit with shell scrapers or use their teeth if it is very ripe. The fruit is cored and torn into lumps and packaged in breadfruit leaves and tied with dry pandanus leaves. These leaf packages are placed in an earth oven for two hours. The next day the packages are opened and emptied into a bowl. The women mash the contents into a yellow paste. This mass is spread out by hand in the sun on mats of green woven coconut leaves. The women go over the past carefully removing any lumps. After several hours the paste is turned to dry on the other side. At this point the men take over and roll the breadfruit paste into packages of pandanus leaves tied around with 2 ply cord. The packages when finished, as recorded by Buck (1950:38), are 19 inches long and 3.8 inches in diameter. This preserved breadfruit is said to keep a long time and is used as a reserve food and a suitable provision for a long voyage at sea. As needed, one end of the roll is opened and the desired portion is cut off.

Miller (1958:31) devotes several pages to the composition and nutrative value of breadfruit in various stages of maturity, cooked and uncooked. She states that breadfruit may supply all the caloric needs of a moderately active islander. One thousand grams of breadfruit a day would supply one-fifth the protein, one-fourth the calcium, almost all the phosphorus, more than half the iron, negligible amounts of provitamin A, one-half to two-thirds of the thiamine, about one-half of the vitamin C needed. Fish and coconut would be required to supply the protein and fat. Some source of provitamin A would be needed, but pandanus, if in season, could solve that. Preserved breadfruit, because of the soaking, washing and pounding, has reduced the amount of water soluable vitamins. The dried preserved breadfruits would have considerable vitamin C loss, (Appendix: table 1).

PANDANUS

The pandanus is native to the Pacific. The tree is dioecious and the edible portion grows on the female tree. The pandanus is an important seasonal food in Kapingamarangi, the Marshalls, Gilberts and Ellice Islands. The pandanus fruitlets or keys contain a sweet juicy pulp that is eaten raw or cooked. A 30 pound fruit can have as many as 50 keys. This edible portion can also be preserved as a dried paste and as a flour. Pandanus, like breadfruit, is also prominent in the folklore of the Marshalls and Gilberts and is thought to have come to them at the time of creation. In the Marshalls each family owns several trees, cutting the fruits when they are ripe and processing them as desired. Pandanus is in season approximately from January to May.

The most common way of eating pandanus is to chew on the inner soft end. In the raw state the edible portion is a juicy liquid which is sweet and pungent. In the cooked state the starch causes the juice to thicken and the edible end becomes soft and pulpy, which as stated by Miller (1958:71) resembles mashed potatoes. According to Buck (1950:286) in Kapingamarangi the keys are cooked in an earth oven and eaten by hand. The dried eaten keys are stored and used for fuel. This might have some implications for fuel on voyaging canoes.

In the Marshalls a pandanus paste called <u>mokan</u> is made by cooking the pandanus keys in an earth oven for one or two days. The soft ends of the keys are scraped with a shell scraper and the orange colored pulp is collected and dried on leaves and further dried on hot stones. Flat cakes are formed and pressed into a solid mass and wrapped in plaited pandanus leaves and tied around with coir cord in a way extremely similar to the methods used in tying up the breadfruit manakajen. The pandanus paste is brown in color and tastes like fig paste. It will keep a year or more and was important for use on voyages and in case of famine.

Pandanus paste is made into a flour in the Gilberts and in Kapingamarangi. Both Grimble (1933) and Buck (1950) give detailed descriptions of the manufacture of pandanus flour. In Kapingamarangi, according to Buck, the pandanus paste cakes are allowed to further dry and when completely dry and hard they are beaten and pounded on a board until a fine powder is formed. This pandanus flour could be kept and used as desired, at which time it is mixed with water to make a porridge.

In the Gilberts, according to Grimble (1933:36), the pandanus flour, called kabubu, is made from pandanus paste with great care taken to expell every possible amount of moisture as the keeping qualities depend on the amount of desication. When the slabs are completely dry they are broken up into bits and thrown into a giant Tridacna shell and pounded into flour with a wooden pestle of pemphis wood. The resulting kabubu is packed into prepared tabular containers of pandanus leaf and will keep for as long as two years. This is one of the most sustaining foods known to the Gilbertese and according to Grimble (1933:39) was an ideal food for voyages in the early days. "As long as a canoe's company had kabubu and water they could venture on a voyage of any length."

The nutrative value of pandanus paste contains little or no fat or protein, and is about 18 percent carbohydrate. The carotenoid pigments which color the fruit a red-yellow may be the only source of provitamin A available. It is not rich in thiamine and riboflavin and is a poor source of vitamin C. However, if eaten in large quantities the vitamin C and riboflavin and thiamine content could meet the needs of the body, the dietary requirements for which are calculated for a medium build person in a warm climate, (Appendix: table 2).

CYRTOSPERMA

In considering possible voyaging foods within the frame of referrence of this paper, *Cyrtosperma* and taro are obvious candidates. According to Barrau (1956:6), *Cyrtosperma*, a native of South East Asia, is the taro of the Micronesians. It grows well in a swampy situation and its yield is greater than taro, thus the Micronesians have largely replaced their taro with it, even though the taste and texture are inferior to taro. According to Buck (1950:281) *Cyrtosperma* was introduced into Kapingamarangi in post contact times by a European sea trader.

Cyrtosperma produces corms which may be harvested young, but can grow to enormous size. Nowhere could I find referrence to poi being made by the Micronesians out of taro or *Cyrtosperma* except from my interview with Mr. Donald Anderson from Lyon Arboretum. However, both the raw and cooked corms of both taro and *Cyrtosperma* would be excellent voyaging foods as they would keep for about two weeks.

Cyrtosperma and taro have about the same caloric value. The calcium content of the *Cyrtosperma* varies with the area of its cultivation. *Cyrtosperma* has less than half the thiamine than the taros, but the same amount of riboflavin and niacin. They have no provitamin A or vitamin C.

Alocasia, another *Areceae* is a much hardier plant, but is not popular and is eaten when other supplies of food are short. It does not have corms and the starchy stem is the portion eaten. It is of lower nutrative value than the other starchy roots, (Appendix: table 3).

COCONUT

The coconut, (*Cocos nucifera*) geographically dispersed throughout the Pacific, is generally thought to have been spread by man and ocean currents (Edmonson 1941). The coconut is extremely important to the Micronesians and every part of the tree is used. The unhusked nuts can be kept for many months and are edible at every stage including the sprouting stage. When taken on voyages the husks can be used as fuel.

A variety of foods can be made from coconut. Discussed here will be foods with preservation possibilities and thus having potential for use in long voyaging. Top consideration is given to the nut itself. Each stage of edibility of the nut is noted and named by the Micronesians. Grimble (1933:30) notes 17 different stages named by the Gilbertese.

As a drinking nut the coconut offers a clean cool beverage. The soft meat of the drinking nut is easily scraped out and is often fed to babies. At the mature stage the coconut is grated and coconut cream is made to be added to a wide variety of dishes. Coconut embryo is a delicacy in the Marshalls and is best eaten 4 months after the coconut falls from the tree.

Coconut toddy or sap collecting is practices by Micronesians and Grimble (1933:33) describes Gilbertese preparation methods as follows:

> Toddy is the sap extracted from the coconut blossom before the hard spathe which contains it has burst. The tip of the spathe is cut off, exposing an inch or two of compressed unopened blossom. The spathe is then bound around with string, in the manner of a cricket bat handle, upward from the base to the cut-off end. A section of the exposed blossom is shaved off and the toddy oozes from the cut surface...a coconut shell suspended below the tip catches the sweet liquid.

The toddy ferments in about fifteen hours and is a popular intoxicant. However, according to Grimble (1933:34) a preserved food is made from it called kamaimai which is obtained by boiling the mixture to almost a solid state until it becomes the consistency of caramel. At this stage it is formed into a ball and set aside for storage. It is taken out when needed and pieces are sliced off. It is eaten as a relish and a sparing amount is considered enough.

The nutrative value of the liquid from drinking nuts is little or none. The mature meat is high in fat and low in protein. Minerals and vitamin content are low except for iron. Coconut sap or toddy is high in vitamin C and is recommended by Miller (1958:62) for children as the niacin and thiamine value are higher than mothers' milk. The amount of calcium is not significant, but the iron content is fairly high, (Appendix: table 4).

OTHER FOODS

The Micronesian diet receives its protein from seafood. Little is recorded concerning the methods of drying fish, either for preservation in times of scarcity or for provisioning canoes for voyages. On the atolls perhaps this is because of the presence of lagoons and thus an availability of fish in all weather conditions, as well as ease in netting and trapping them. In looking at other sources of animal protein, the pig is considered to be an European introduction (Grimble 1933:29). However, fruit bats and large birds were hunted on larger islands. According to Buck (1950), on Kapingamarangi pigs are a post contact food and fowls are of little or no interest to the people there.

It is interesting to note briefly the absence in Micronesia of some cultivars which are strong parts of the culture among the Polynesians and Melanesians. Sago, which is a large part of the diet in Melanesia and grows wild in the river swamps, is used to prepare a starch which is made into cakes and keeps well for several months. According to Dr. Harold St. John (1973:9), the sago is cultivated as far north as Guam, but it is not utilized by the Micronesians.

Kawa or awa, which is a common beverage among the Polynesians, is reported by Barrau (1956:44) to be drunk only among a small population in the area of Ponape in the Carolines. The betal palm, according to Grimble (1933), does not grow in the Gilberts, but is present in traditional legends which tell of ghosts eating the "red food."

Although this survey discusses preserved foods that can be readily eaten without cooking, there is evidence that food was cooked aboard voyaging canoes. That it is being done now in the Carolines is mentioned by Gladwin (1970:60) when he relates that a fire was made aboard a canoe albeit in an iron box filled with sand. Dodd's book, Polynesian Seafaring, 1972, states that the double canoes carried a sandbox forward and most likely a fire was kept going most of the time. Dodd contains two illustrations of Tongan canoes (Dodd 1972:73-74), one drawn by Tasman in 1642 and one by Shouten in 1616. Both depict billowing smoke from a fire on board. One fire is confined to a box and another appears to be out on the open deck. Hornell (Hornell 1936) does not mention specifically that fires were used on board, but a superficial glance through the illustrations would indicate that many of the canoes were large enough to have a fire area.

TRANSPORTATION OF CULTIVARS

It is obvious that cultivars had to be transported from island to island in Micronesia. I interviewed Mr. Donald Anderson of the Lyon Arboretum as he has had considerable experience voyaging from island to island in native craft while working for a supply company some years ago in the central Carolines. Mr. Anderson has also spent some time in Fiji and the Tuamotus and I consider his information valuable as it shows a contrast and comparison. According to Mr. Anderson, the Carolines people transport their cultivars in much the same way as the Fijians and Tuamotuans. For example, in all places the rooted cultivars were wrapped in well rotted coconut husk fiber. Most carefully tended were the breadfruit shoots as they are extremely delicate and tender. Mr. Anderson states that the secret of transporting breadfruit shoots is to let the root sucker gain several years growth so that hard wood is present. At this point the roots are balled in coconut husk fiber and the whole thing is wrapped in dried leaves, different kinds of leaves being used depending on the area. Then a coconut basket is woven around the entire sucker. This is done with each individual plant.

In fact, every cultivar was packaged in such a manner, that is, with a coconut leaf basket woven around it. These people understood the devastation of salt water upon root tips. When a root tip encounters salt water it is killed and another root tip has to form, keeping the plant in a period of suspended growth. If the intent of the voyage was to colonize, this could be quite a setback. The woven basket method must have been quite successful.

In discussing Cyrtosperma, Mr. Anderson says that it was cut in half lengthwise and stacked in the um or earth oven between layers of stones. After the first cooking the Cyrtosperma was still what he called "mane'o" or itchy, referring to the calcium oxalate taro contains, which is irritating to the lining of the throat and mouth unless the taro has been thoroughly cooked. It was grated, mixed into cakes and allowed to ferment. It was then recooked. He says that it tasted like sour poi and looked grayish yellow.

He mentioned more than once, and quite poignantly, the repetition of bailing the canoes. He said that sometimes all he did was scoop water. He also added that the natives always had a hand line out fishing while in their canoes. He said even if they were paddling there would be a hand line out.

A NOTE

Something should be said about Andrew Sharp's (1963) statements on cultivar and animal transportation. He suggests one theory that a canoe full of pigs, dogs and chickens broke loose from somewhere and drifted to another island, washing ashore there and thus inhabiting the island with animals. Dodd (1972:156) puts this to rest by asking the question as to who was to feed these animals as they drifted about in the Pacific Ocean. I also add that there must have been a male and female of each species, or at least gravid females, in order to have a viable population. On a minor point, Sharp (1963:94) further states that "The great majority of useful plants found on the farther Polynesian islands could be grown from seeds occupying little space in transport." However, in tabulating the 27 to 29 cultivars thought to be of Polynesian introduction, only 9, I feel, could have been propagated by seed.

APPENDIX

Nutrients	100 g.	E.P. of ½ med. or 1 small, 250 g.	E.P. of 1 med. or ½ large, 500 g.	E.P. of 2 med. or 1 large, 1000 g.
Calories	128	320	640	1280
Protein, g.	1.4	4	7	14
Calcium. mg.	21	52	105	210
Phosphorus, mg.	52	130	260	520
Iron, mg.	0.8	2.0	4.0	8.0
Vitamin A, I.U.	10	25	50	100
Thiamine, mg.	0.08	0.2	0.4	0.8
Riboflavin, mg.	0.08	0.2	0.4	0.8
Niacin, mg.	1.21	3	6	12
Ascorbic acid, mg.	4.0	10	20	40

Table 1. Nutritive value of various quantities of breadfruit. (Murai 1958:30)

Nutrients	1 key 75 g.	5 keys 375 g.	10 keys 750 g.	20 keys 1500 g.
Calories	53	265	530	1060
Protein, g.	0.28	1.4	2.8	5.6
Calcium, mg.	7.2	36	72	144
Phosphorus, mg.	19.4	97	194	388
Iron, mg.	0.7	3.5	7.0	14
Carotene, mcg.	932	4660	9320	18640
Thiamine, mg.	0.02	0.1	0.2	0.4
Riboflavin, mg.	0.03	0.15	0.3	0.6
Niacin, mg.	0.7	3.5	7	14
Ascorbic acid, mg.	2	10	20	40

Table 2. Nutritive value of the edible portion of various quantities of large pandanus keys. (Murai 1958:78)

APPENDIX (cont'd.)

Nutrients	100 g.	300 g.	500 g.	750 g.	1000 g.
Taro					
Calories	153	459	765	1148	1530
Protein, g.	1	3	5	8	10
Carbohydrate, g.	37	111	185	278	370
Calcium, mg.	26	78	130	195	260
Phosphorus, mg.	51	153	255	382	510
Iron, mg.	1.0	3.0	5.0	7.5	10.0
Thiamine, mg.	0.092	0.28	0.46	0.69	0.92
Riboflavin, mg.	0.030	0.09	0.15	0.22	0.30
Niacin, mg.	0.85	2.6	4.2	6.4	8.5
Cyrtosperma					
Calories	131	393	655	982	1310
Protein, g.	0.9	3	4	7	9
Carbohydrate, g.	31	93	155	232	310
Calcium, mg.	(334)	(1002)	(1670)	(2505)	(3340)
Phosphorus, mg.	56	168	280	420	560
Iron, mg.	1.2	3.6	6.0	9.0	12.0
Thiamine, mg.	0.045	0.14	0.22	0.34	0.45
Riboflavin, mg.	0.074	0.22	0.37	0.56	0.74
Niacin, mg.	0.88	2.6	4.4	6.6	8.8

Table 3. Nutrients from various quantities of two starchy aroids (Murai 1958:99)

Nutrients	Coconut sap					Embryo				
	100 g.	200 g.	300 g.	500 g.	1000 g.	100 g.	200 g.	300 g.	400 g.	500 g.
Water, g.	87.5	175	262	438	875	83.4	167	250	334	417
Calories	48	96	144	240	480	80	160	240	320	400
Protein, g.	0.22	0.4	0.7	1.1	2.2	1.30	2.6	3.9	5.2	6.5
Fat, g.	0.40	0.8	1.2	2.0	4.0	4.08	8.2	12.2	16.3	20.4
Carbohydrate, g.	11.40	22.8	34.2	57.0	114.0	10.28	20.6	30.8	41.1	51.4
Calcium, mg.	0.4	0.8	1	2	4	19.2	38	58	77	96
Phosphorus, mg.	20.0	40.0	60	100	200	66.1	132	198	264	330
Iron, mg.	0.18	0.36	0.54	0.90	1.8	0.69	1.38	2.07	2.76	3.45
Thiamine, mg.	0.016	0.032	0.048	0.08	0.16	0.015	0.030	0.045	0.060	0.075
Riboflavin, mg.	0.006	0.012	0.018	0.03	0.06	0.032	0.064	0.096	0.128	0.160
Niacin, mg.	0.48	0.96	1.44	2.4	4.8	0.86	1.72	2.58	3.44	4.30
Ascorbic acid,mg.	20.6	41	62	103	206	6.0	12	18	24	30

Table 4a. Nutritive values of various quantities of coconut sap and of embryo from sprouted coconut.

(Murai 1958:63)

Nutrients	100 g.	200 g.	300 g.	400 g.	500 g.
Energy	414	828	1242	1656	2070
Protein, g.	4.0	8.0	12.0	16.0	20.0
Fat, g.	40.4	80.8	121.2	161.6	202.0
Carbohydrate, g.	15.4	30.8	46.2	61.6	77.0
Calcium, mg.	14	28	42	56	70
Phosphorus, mg.	101	202	303	404	505
Iron, mg.	2.2	4.4	6.6	8.8	11.0
Thiamine, mg.	.040	.080	.120	.160	.200
Riboflavin, mg.	.014	.028	.042	.056	.070
Niacin, mg.	.613	1.226	1.839	2.452	3.065

Table 4b. Nutrients from various quantities of mature coconuts.
(Murai 1958:55)

REFERENCES CITED

Alpert, Elmer
1946 Nutrition and Diet. Honolulu: U.S. Commerical Company. Economic Survey of Micronesia... Vol. 14.

Barrau, Jacques and Emile L. Massol
1956 Food Plants of the South Sea Islands. Technical Paper 94. Noumea, New Caledonia: South Pacific Commission.

Buck, Peter Henry
1950 Material Culture of Kapingamarangi. Bulletin 200. Honolulu: B.P. Bishop Museum.

Dodd, Edward Howard
1972 Polynesian Seafaring; a Disquisition on Prehistoric Celestial Navigation and the Nature of Seagoing Double Canoes... The Ring of Fire, Vol. 2. New York: Dodd, Mead and Co.

Edmondson, Charles Howard
1941 Visibility of Coconut Seeds After Floating in Sea. Occasional Paper 16. Honolulu: B.P. Bishop Museum.

Gladwin, Thomas
1970 East is a Big Bird: Navigation and Logic on Puluwat Atoll. Cambridge, Mass.: Harvard University Press.

Grimble, Arthur
1933 The Migrations of a Pandanus People... Journal of the Polynesian Society Memoir 12.

Haddon, Alfred Cort and James Hornell
1936 Canoes of Oceania. Special Bulletin 27. Honolulu: B.P. Bishop Museum.

Lewis, David
1973 We, the Navigators; the Ancient Art of Land Finding in the Pacific. Honolulu: University Press of Hawaii.

Murai, Mary, Florence Pen and Carey D. Miller
1958 Some Tropical South Pacific Island Foods: Description, History, Use, Composition, and Nutritive Value. Hawaii Agricultural Experiment Station Bulletin 110. Honolulu: University of Hawaii Press.

Neal, Marie Catherine
1965 In Gardens of Hawaii. New and Rev. Ed. Special Publication 50. Honolulu: B.P. Bishop Museum.

St. John, Harold
1973 List and Summary of the Flowering Plants in the Hawaiian Islands. 1st Ed. Memoir 1. Lawai: Pacific Tropical Botanical Garden.

Sharp, Andrew
1963 Ancient Voyagers in Polynesia. Sydney: Angus and Robertson.

INTERVIEW

Anderson, Donald
1975 Personal Interview. Technician (retired) Lyon Arboretum, Honolulu.

Reading Three

HAWAIIAN 'INITIAL SETTLEMENT'

A POSSIBLE MODEL

Patricia Price Beggerly

TABLE OF CONTENTS

Page

INTRODUCTION

One of the newer methods that archaeologists are using to discover patterns of change is an analytical approach whereby a model of the past is constructed against which the archaeological data are examined (Groube 1967).

The simplest of these models is a 'time chart' with the evidence from different proveniences examined against an absolute or relative time scale. However, even though great strides are being made in dating technology, many sites do not reveal datable samples and often the material has been contaminated by natural or human agencies.

Prior to the technological advances of C-14 dating, a 'stadial model' was used by most European prehistorians. This model is an abstract construction of a series of stages in cultural development which have chronological order but no absolute time positions. An example of a stadial model is Thomsen's three age system; stone, bronze and iron. This system was based upon man's technological expertise and included a concept of progression from simple to complex. Later researchers (Morgan, 1877; Braidwood, 1960) have added the dimensions of sociology and economics to Thomsen's technological criteria and the stages have been defined by more complex variables which are based primarily on socio-political developments rather than technology.

Hawaiian archaeology has not yet progressed to the point where absolute time periods may be constructed for Hawaiian prehistory, nor have many 'stadial models' been proposed. A two-stage settlement period for the Hawaiian Islands, first from the Marquesas and then at a later period from the Society Islands based on glottochronology and tool technology has been postulated (Emory 1959, 1963; Emory, Bonk and Sinoto 1959; Emory and Sinoto 1964; Sinoto 1968). Newman (1969) has set forth a sequence of development based on ecological assumptions which at this time is still speculative and has not been tested archaeologically. Cordy (1974) has recently postulated that two major cultural adaptations were evident in Hawaiian prehistory (1) a subsistence adjustment to two different physical environments, and (2) the development of complex ranked social systems. He further postulated that the sequence for this development was:

1. Initial Settlement Period
   Simple ranked societal levels and permanent settlement in the wet windward and stream-leeward areas which would be favorable to agriculture.

2. New Adaptation Period
   Simple ranked societal level. Spread into and exploitation of less favorable agricultural areas of dry-leeward portions of the islands.

3. Complex Chiefdon Period
   Marked ranking (two to three redistributive levels). Large political units (district or island-wide in size).

Cordy has supported the Wet Windward Initial Settlement Period with an analysis of the archaeological data (primarily tool inventory and settlement patterns) from the Bellows Site, Oahu (0-18) and the Halawa Sand Dune Site, Molokai. He makes no claim that these sites represent the earliest or initial settlement of the islands, but rather, indicates they are the earliest yet excavated. The belief that the original settlement area of Hawaii has not yet been located is also stated by Kirch (1973) and Newman (1969).

The original homeland of the 'initial settlers' of Hawaii is unknown at this time, however, recent research (Emory 1958, 1963; Emory, Bonk and Sinoto 1959; Emory and Sinoto 1964; Sinoto 1968) indicates they may have originated in the Marquesas. Therefore, for purposes of this presentation it will be assumed that it was physically possible for a double canoe to be sailed from the Marquesas to Hawaii and that it was possible for immigrants from this area to be the 'initial settlers' of the Hawaiian Chain.

Because it is not within the scope of this paper to examine all the aspects of the three Hawaiian stadial models, I will address this paper only to Cordy's (1974) 'Initial Settlement Period.' However, an area of settlement will be proposed that differs from either Cordy's (1974) 'wet windward/stream leeward' model or Newman's (1969) 'leeward' model. The ecobelt which I propose binds together the optimal environmental zones of both wet and dry microenvironments and would have allowed the 'Initial Settlement Group' to exploit a wide diversity of resources which would have magnified their chances for survival. Within the postulated area of settlement the possible native resources, i.e., fresh water, bird, marine and vegetable will be examined. An abstract group will be proposed upon which likely population growth might be tested. After a discussion of some of the problems that might have been encountered by this group and possible ways they solved these problems, I will briefly examine the archaeological data now available for a similar environment. In conclusion, I will propose possible ways the postulated ecobelt might be tested archaeologically.

AREA OF SETTLEMENT

I have chosen as a possible area of initial settlement the north windward coast of Oahu; more specifically a 2½ mile wide ecobelt which extends from Kaiaipaloa Point to Laie Bay and includes portions of both Hauula and Laie.

Although Marquesan sailing canoes could probably not have sailed directly to this area (Finney private intermiew) it would be unlikely that they would have chosen their first landfall as a settlement area; but rather, would seek out an area they considered the best possible for their survival. If they had sailed first into the leeward area of Oahu it would be entirely within the realm of possibility that they could have continued around the southern portion of the island and up the windward coast (Finney private interview).

Because this group had just survived a very long and strenuous trip in an open canoe it is quite probable that their personal physical resources were at a very low ebb. It would therefore be of major importance that the area they chose included environmental zones that closely matched the requirements of a large percentage of the cultigens they had brought with them from their homeland (see pp. 80, 81) and further, that these environmental zones could be exploited with the least amount of energy expended, particularly during the first few months of habitation.

A dependable and consistent source of fresh water would also be a primary consideration, not only for human consumption, but also as a major requirement for both plants and animals.

In addition, until their plants had survived and matured in sufficient quantities to support the colony they would have had to rely primarily on fish, shellfish and native vegetable food for their survival. Although most areas along the windward coast of Oahu yield some type of seafood, it would be important to select an area where the fish were readily available during a major portion of the year and would not require a large expenditure of manpower. This would allow a majority of the group to be engaged in such necessary activities as clearing land, planting and caring for the agricultural products, penning the livestock to prevent them from destroying the tender new growth of the plants, constructing canoe sheds and shelters for the group, seeking out additional food resources among the native plants of the island, discovering quarries of basalt and volcanic glass for tools, seeking raw materials for clothing, shelter, medicine, baskets, bowls, knives, utensils, and the myriad other needs of a colony in a new land. Further, a great deal of energy and resourcefulness would be needed for discovering which native materials could be used for ropes, lashings, caulking and other items which would be required to repair or maintain their canoe and to keep it seaworthy.

A further consideration would be the necessity of a somewhat calm harbor where the canoe could be easily beached and ideally this harbor would be near a break in the reef which would allow them an exit to the open sea.

Most Hawaiian archaeology in recent years has tended to be centered around the investigation of change through time within specific areas, usually conceived of as an ahupua'a which Handy and Handy (1972:48) describe as,

> . . . a wedge from sea to mountains . . . including fishing rights, cultivable lands, upland timber and planting zones, and areas of valuable bird-catching privileges in the higher mountains.

Therefore the primary controversy in regard to initial settlement has not been centered around the concept of microzones dependent primarily upon altitude from sea to mountains, but rather, around whether dry leeward (Newman 1969) or wet windward/leeward (Cordy 1974) areas were settled first.

Predicated on the above criteria I would like to suggest that the 'Initial Settlers' sought neither a wet nor a dry ecological zone, but rather an area that included both of these extremes plus all the other resources usually included in the concept of ahupua'a as stated above. I would also like to suggest that the ecobelt mentioned earlier from Kaiaipaloa Point to Laie Bay, Oahu included all of these ecozones as well as the availability of the following resources.

FRESH WATER

At the present time, within the delineated area there are two fresh water streams flowing from the mountains to the sea as well as three intermittent streams, two of which were continuously flowing during the early 1920's (Preston private interview).

BIRDS

Within this area are five small offshore islands which are presently bird refuge areas, and were probably nesting areas for sea birds prehistorically. In addition, large areas of swampland extended, prior to modern development, between the coastal areas and the mountains which would have been a source of both swamp and pond birds. Within a thirty minute walk from Hauula, forest areas still survive which possibly extended much closer toward the sea prehistorically (Zimmerman 1963) and would have been a resource area for upland birds.

MARINE RESOURCES

Newman (1972) emphasized that the early settlers chose areas of abundant sea resources to colonize and further, they possessed the technology to exploit these resources to their fullest limits. He further indicates that inshore or reef habitats contain the largest marine bio-mass and were the areas most exploited by the early settlers. Within the proposed area, at Hauula Beach Park there is a very large (1,000-1,500 foot) coral reef that abounds in many types of shellfish which are a major food resource for local residents today. In addition, another large reef extends off the southern margin of Laie Point which is presently harvested, but to a lesser degree than the Hauula reef. Bryon (1938) indicates that more then 20 species of fish are available in the mouths of streams, and since the proposed area includes five streams, this would have presented them with the added resource of stream-mouth species. Deep water fishing is also available beyond the reefs in this area and possibly was an important resource zone for the 'Initial Settlers' as this type of fishing would have been more familiar to a Marquesan immigrant (Suggs 1960:110) who primarily fished for tuna, bonito, and wahoo in his homeland. The importance of this type of fishing possibly gave way, through time, to shellfish harvesting of the reef areas as this would have required less expenditure of time and energy to fulfill protein and caloric needs.

PLANTS

The ecobelt proposed would particularly be a good source of vegetable foods. In the uplands and forest areas the various berries and ferns would be available for food as well as the forest products for construction material (Bryan, n.d.). And although Zimmerman (1963:57) discounts the importance of native vegetable foods, I propose the tree fern hapu'u i'i (Cibotium chamissoi) could have been of major importance to the 'Initial Settlers.' In addition, if the early settlers arrived with viable cultigens of sweet potato and taro, the area proposed would be suitable for planting both of these vegetable foods which appeared to be the major food resources of the early Hawaiians at contact time (Cook 1967). Usually, the sweet potato (Ipomea batatas) is associated with very warm dry leeward areas which are unsuitable for taro (Colocasia esculenta) crops unless extensive irrigation systems have been constructed and conversely taro is associated with wet windward or stream/ leeward areas (Cordy 1974) where they are watered by either artificial or natural agencies and these areas, although sometimes supporting sweet potato crops, are not considered optimal environments for these plants.

The proposed ecobelt includes areas which are prime microenvironments for the cultivation of both these crops. Today home gardeners in Hauula, which has an annual mean rainfall of approximately 59.27 inches per year, (Hawaii Water Authority 1959; U.S. Weather Bureau n.d.) are unable to grow such plants as tomatoes or cucumbers unless extreme measures are taken to protect them from mildew and rot (Marsden private interview). This area has historically been a major source of _taro_ for the local residents which has been grown along streams, in swamps, in irrigated _taro_ patches, and more recently in home gardens (Preston private interview). However, in the Laie area, which has an annual mean rainfall of 44.4 inches per year, (Blumenstock and Price 1967; Hawaii Water Authority 1959; U.S. Weather Bureau n.d.) these plants and others such as the sweet potato which require a dryer environment thrive and in many places are found growing wild.

Therefore, because of the large number of resource areas included in this ecobelt, and the relatively low expenditure of time and energy needed to exploit these resources, I propose the area from Kaiaipaloa Point to Laie Bay may have been an 'Initial Settlement Area' for possible Marquesan immigrants.

NATIVE RESOURCES

In the foregoing section I have mentioned that the proposed area of 'Initial Settlement' contained possible resources other than those brought as cultigens or animals by the immigrants from their homeland. At this time I would like to present a more detailed description of the possible resources and when (seasonally) they may have been available.

BIRDS

Birds may have been an important resource for the 'Initial Settlers' of Hawaii. However, because 80 percent of the native Hawaiian birds are recently extinct (Zimmerman 1963) it is difficult to make any firm statements regarding exactly which birds may have been available as a food source. Malo (1971), who wrote in the early 1800's, does shed some light on this problem as he lists the bird resources available at that time. However, there is some ambiguity in his information as he does not always distinguish between birds caught for their plummage and those used for food. Handy and Handy (1972) drawing primarily on Malo as a source also offer some new information. Based on these two sources the following bird resources would probably have been available within the various microenvironments of the proposed Hauula/Laie ecobelt.

Sea Birds

Live in mountains during night, return to sea during day

Hawaiian Name	Generic or Common Name
lu-ukai	
kiki	
a'o	Puffin (*Puffinus newelli*)
'ua'u	Petrel (*Pterodroma phaeopygia*)
'o'u'o'u	(*Psittirostra psittacea*)
puha-aka-kai-ea (noio)	(*Anous minutus melanogenys*)
koa'i	(*Phaeton rubricauda*)

Captured on offshore islands

'a	Booby (*Sula spp.*)
moli	Laysan albatros (*Diomedea*)
'iwa	Frigate bird (*Fregata minor*)
kala	(*Sterna panava*)
na-u-ke-wai	

Pond and Swamp Birds

koloa	Duck (*Anas wyvilliana*)
'alae	(*Gallinula chloropus*)
'auku'u	Heron (*Ardea sacra*)
kuku-luae'o	Stilt (*Himatopus himatopus*)
kioea	Wader (*Numenius tahitiensis*)

Upland Bird

nene	Goose (*Bernicla Sandvicensis*)

Forest Birds

'o'u	Honeysucker (*Psittirostra*)
'oma'o	Thrush (*Phaeornis obscura*)
'o'o	Honey eater (*Acrulocerous spp.*)
mamo	(*Drepanis pacifica*)
'apapane	(*Himatione sanguinea*)
'akini-polena	
'ula	(*Phaethon lepturus dorotheae*)
u'a	
'akohekohe	(*Palmyria dolei*)
mu	
'amakihi	(*Loxops spp.*)
'akihi-a-loa	(*Hemianathus spp.*)
'elepaio	(*Chasiempis*)

Other

'alala	Raven (*Corvus Hawaiiensis*)
moho	Rail (*Pennulo millsi*)

In addition to the above, Handy and Handy (1972) list several other birds which migrate, however it is unclear if these are additional species or the common name for already mentioned Hawaiian birds. They are ruddy turnstone, wandering tattler, sanderlings, and pintail and shoveler ducks. These and other migrating birds would have been available in January and February only.

No mention is made in the early literature regarding the use of bird eggs as food; Handy and Handy (1972) believe they were distasteful to the Hawaiians, but Zimmerman (1963) cites them as a possible food resource.

Although it is unknown how important bird resources were to the early immigrants, it would appear that some of them could have been major sources of food. The nene (Bernicla Sandvicensis), koloa (Anas wyvilliana), na-u-ke-wai, moli (Diomedea immutabilis) and 'iwa (Fregata minor palmerstoni) are listed by Malo (1971) to be as large as turkeys or ducks, and the moho (Pennulo millsi) and 'alae (Gallinula chloropus) to be the size of domestic fowl. If these birds were available to the 'Initial Settlers' they could have served not only as an additional source of protein, but would also have added variety to their diet.

MARINE RESOURCES

Malo (1971) lists a total of 168 different fish and shellfish which were utilized by the Hawaiians of his time. He further indicates that he has probably not listed all of them. It is also quite likely that many species had been overfished by the 1800's and therefore not included in his list. There appears to be some indirect evidence that this might have happened since the culture had elaborate kapu systems that protected different species at different times, particularly during breeding seasons. A further indication is the progressive elaboration of fishponds during later Hawaiian history which might also reflect an earlier overfishing of certain species plus the need for constant nonfluctuating availability of sea resources as population pressures became more acute. However, when the first settlers arrived here they entered an area where fish were probably quite abundant and further the fish may not have developed behavioral patterns that would have made them wary of man or his fishing techniques.

If the 'Initial Settlers' arrived in the Hawaiian Islands during the months of March through October and if they were Marquesans with considerable skill in deep sea fishing this probably was the primary source of protein during the first few months of settlement. However, if they arrived during the winter months or late in summer the high seas prevalent along the north windward coast of Oahu and the seasonality of many of the deep sea species would possibly have prevented their use of this resource to any great degree. This may also help explain the later importance of shellfish resources in relationship to deep sea fishing which was only supplementary (Newman, 1972). As mentioned earlier the proposed ecobelt of original settlement contains two large reefs for both extensive and intensive exploitation of these resources, as well as an open passage through the reef to areas of deep sea fishing.

A third important zone of fishing within the proposed 'Initial Settlement' area is one of inshore fishing. The presence of fresh water streams which open into the sea often form channels which contain large amounts of marine life (Reinman 1967). Two of the five stream outlets are still extensively exploited today using both modern and prehistoric fishing technology such as poisoning, probing spears, nets and traps, hand collecting and torch fishing (Newman 1972; Reinman 1967; Bryan 1938; Jarves 1847).

A further marine resource used by the Hawaiians was <u>limu</u> (seaweed) (Handy and Handy 1972; Buck 1964). This resource is particularly abundant along the north windward coast of Oahu and would possibly have been available to the early settlers. Miller (1927), however, tested several species for their vitamin content and found they are a poor source of both Vitamin A and B and further their carbohydrate content is not utilizable by man. Their extensive use by early Hawaiians may be explained by their spicy flavor which would add variety to the diet.

It is therefore suggested that the proposed 'Initial Settlement' area had a more than adequate supply of marine resources to not only supply the original colonizers, but to sustain them for a considerable time during which their population would be increasing in a geometrical pattern.

PLANTS

Food Products

A great deal of controversy centers around the issue of which vegetable foods were native to the Hawaiian Islands and which were introduced by human agency. It appears that part of the problem lies in the fact that one of the early writers, Malo (1971) listed a number of food plants used in famine times and implied that these foods were native to the Islands; possibly because at that time they were growing wild in uncultivated areas. Early errors such as these were repeated in many publications through the years (Kelly 1967), but have recently been challenged by modern research. Therefore many of the plants which were originally identified as native have recently been classified as early introductions by aboriginal populations (Krauss 1972; Gutmanis 1975; Fosberg 1948; Rock 1974; Pope

1926; Zimmerman 1963).

To further complicate this problem, two of the basic resources of the Hawaiians at European contact (Cook 1967), taro (Colocasia esculenta) and sweet potato (Ipomea batatus) have the characteristic of reverting to a more ancient state when left uncultivated. When the sweet potato (Ipomea batatus) is cultivated, as soon as the vine shows sturdy growth it is turned under around its own base which induces the plant to put its growing energy into tubers; if left to grow wild the plant tends to send out long shoots and have little tuberous growth. Wild taro (Colocasia esculenta) is also characterized by an unusual growth pattern. The wild taro plant has small corms and long rhizomes which send out shoots that eventually form new individual plants and are found primarily along stream banks in the mountain areas. Handy and Handy (1972) believe that these wild taro plants were either planted originally as an insurance against famine or possibly represent plants which have been washed down to lower elevations by stream action. However, they also indicate that one type of taro, Mana 'ele'ele has successfully been propagated by seed and therefore could have been introduced by other than human agency.

Further controversy centers around the coconut (Cocus nucifera). Several researchers have tested the viability of coconut after immersion in salt water with varying results. Edmondson (1941) indicates that they are unaffected by sea water and will germinate even after 110 days of exposure. He further states that germination may begin and continue while immersed and the presence of sea water within the shell has no deleterious effect on this germination.

Another plant around which controversy is centered is the hala tree (Pandanus odoratissimus). Zimmerman (1963), Newman (1972) and Handy and Handy (1972) state this is a native tree; however, Schattenberg (private interview) indicates that there is some controversy centered around this plant and its origin. If it was available to the 'Initial Settlers' it would possibly have been an important food resource (as it is in the Marshall, Gilbert and Ellice [Tuvalu] Islands) for it contains phosphorus, calcium and iron contents which are comparable to temperate climate fruits such as peaches and apricots (Miller, et al. 1956).

Ti (Cordyline terminalis) is listed by Malo (1971) as a famine food, particularly the root which was baked before eating and which MacCaughey (1917) describes to be very delicious due to its rich sugary flavor. Krauss (1972) indicates this plant represents a fairly late introduction, but Handy and Handy (1972) believe it was native and introduced by seed.

Because of the controversy which surrounds those food plants, they will be considered 'introduced' for purposes of this presentation and will not be considered as available resources for the 'Initial Settlement Group.'

Therefore, the following list of foods compiled from Malo (1971) and Handy and Handy (1972) will include only those foods which are presumed to have been available for the use of the 'Initial Settlers' upon their arrival in the proposed ecobelt.

It is also presumed that a great deal of latitude would have been present for the testing of unknown plants as food resources. Only four plants in the Pacific Area are classified as poisonous by the U.S. Army (Merrill 1943) and these plants are found throughout the Pacific area and may have been known by the 'Initial Settlers'.

Ferns

Hawaiian Name	Generic Name	Portion Used
hapu'u pulu	Cibotium splendens	Flesh stem/leaf
hapu'u i'i	Cibotium chamissoi	Trunk/stem
ama'u	Sadleria spp.	Pithy interior
i'i'i		
keki		Pithy interior
pala	Marattia douglasii	
ho'i'o	Diplazium arnottii	Leaf shoots

Berries and Fruits

'akala	Rubus macraei	Berries
'akala	Rubus hawaiiensis	Berries
'ohelo	Vaccinium reticulatum	
poha	Physalis peruviana	
pa'ina		
ne'ene'e		
pi'oi	Diospyros sp.	Persimmon
ulei	Osteomeles anthyllidiafolia	
loulu	Pritchardia spp.	Palm

Foliage eaten as greens

popolo	Solanum nigrum	Also berries
pakai	Amaranthus dubois	
aweo-weo		
nau-nau	Gardenia brighami	
haio		
nena	Heliotropium curassavicum	
palula		
aneanea	Chenopodium oahuense	
aku-aku	Cyanea rollandioides	

Other

paha	Ipomea congesta	Morning glory vine and tubers
pohuehue	Ipomea pes-caprae	Morning glory roots and vines
pia	Dioscorea pentaphylla	Wild yam
hoi		Aerial tubers

Many of these foods would not have served as important food resources for the early colonizers, either because of the ratio of energy expended vs. calories gained or because of seasonality. Both of the 'akala berries are seasonal, Rubus hawaiiensis fruits between April and July and Rubus macraei between July and November, and would have added only 100 calories per cup to the diet. However, many of these plants may have been considered valuable resources because they added variety to the diet.

One of the native ferns (Fosberg 1948; Malo 1971; Handy 1972; Krauss 1972) hapu'u i'i (Ciborium chamissoi) may have been important to the 'Initial Settlement Group.' The trunk of this fern grows quite large and contains from 50-75 pounds of pure starch (Krauss 1972). One hundred fifty grams of this starch provides 23 grams of protein, 71 grams of fat, and 314 grams of carbohydrate which provides an energy value of 1,990 calories (Langworthy and Deuel, Jr. 1922). One 50 pound trunk which contained pure starch would provide 25 people, 1976 calories per day for 4 days. However, ambiguities associated with the above research make it necessary for direct statements regarding the food value of this plant to be withheld pending further research. Although this particular fern is not found in the Marquesas, other ferns are available and the 'Initial Settlers' may have understood the value of ferns as a food resource. At the present time these ferns are found in the mountain regions within the proposed ecobelt, and possibly were present prior to settlement.

Other than Food Products

In addition to food products the 'Initial Settlers' would have needed many plant products to serve as raw materials for houses, canoe sheds, clothing, baskets, bowls, knives, utensils, agricultural tools, bird catching devices, and fishing gear as well as materials to repair and maintain their canoes. Many of the tree and vegetable products which provided these raw materials as indicated by early ethnographic reports (Buck 1964; Cook 1967; Dixon 1968; Jarves 1847; Malo 1971; Porter 1815) are considered by researchers (Fosberg 1948; Krauss 1972; Gutmanis 1975; Zimmerman 1963) to have been introduced by early Polynesian immigrants. Also, even if cultigens for these plants arrived in Hawaii safely there would have been a considerable time lag between planting and their availability for use. Therefore, it was necessary for the 'Initial Settlers' to discover substitute vegetable products for some of their raw materials.

Because the ancient Hawaiians were particularly adept at exploiting their environment it is not within the scope of this paper to examine all of the possible substitutions, but rather, I will examine the ones which I consider to be critical to their welfare and chances for survival and will propose alternative resources they might have used as substitutes. (For a more complete listing of Hawaiian plants, their uses and food values see Appendix).

Tree Sap

Two needs of the 'Initial Settlers' would be some type of sticky substance to use for canoe caulking and bird lime (the sticky paste used to snare birds). The use of breadfruit gum (<u>Artocarpus aetilis</u>) as caulking for modern canoes is mentioned by both Gladwin (1970) and Lewis (1973). Its use by prehisoric Hawaiians as the raw material for caulking and also for bird lime is mentioned by several ethnographers (Cook 1967; Buck 1964; Malo 1971; Handy and Handy 1972; Krauss 1972). I have classified it as a vital raw material based on Gladwin's (1970) statement that canoes must be recaulked every three months if used intensively and further because the 'Initial Settlers' may have supplemented their basically marine diet with the many birds available within the proposed ecobelt. It is very unlikely that the 'Initial Settlers' would have been able to use breadfruit gum for this purpose, for even if the cultigen was successfully transported and survived transplanting there would be a time lag of about 5-7 years before the tree was mature enough to bear fruit or possibly to tap for gum. Two native plants may have been used for substitutes; 'oha-kepau (*Cyanea solanacea*) which is mentioned by Cook (1967) as a raw material for bird lime, as well as *Pisonia sandwicensis* which contains a very viscid waterproof sap. Although I have suggested *Pisonia sandwicensis* as a possible substitute, it possibly was not as efficient as breadfruit gum as evidenced by the fact that I was unable to find mention of its use by early Hawaiians. However, this might just reflect the fact that breadfruit gum was the best caulking product and when available was preferred over alternate substances.

Cordage

Another vital resource needed by the 'Initial Settlers' was a source from which to make cordage. This source for most of Polynesia and also for Hawaii was the husk of the coconut (*Cocus nucifera*)

(Gladwin 1970; Lewis 1973; Krauss 1972; Gutmanis 1975; Malo 1971; Buck 1964; Handy and Handy 1972). Its extensive use by the Hawaiians might indicate that this was an early introduction by Polynesian immigrants if not introduced by natural agencies. The need for cordage to mend canoes, construct shelters, make fishing line, nets and traps and its many other uses places it in my vital material category. Again, even if the 'Initial Settlers' had brought coconut cultigens, either purposefully or accidentally, there would have been a time lag of about 6-10 years before the tree would have been mature enough to bear nuts. I therefore suggest that the native Hawaiian shrub (Fosberg 1948) olonā (Touchardia latifolia) was substituted for the coconut as a source of raw material for cordage. The use of olonā as cordage is mentioned by both Malo (1971) and Handy and Handy (1972) who state it was of superior quality to coconut cordage and lasted longer. Buck (1964) also mentions two other Hawaiian native plants (Handy and Handy 1972) which were used for cordage, 'uki'uki and 'ie'ie (Freycinetia arborea) in house construction.

Building Materials

Gutmanis (1975) includes within her list of Introduced Plants the following utilitarian wood trees which could have been brought by the 'Initial Settlers' in the form of seeds:

Hawaiian Name	Generic Name
Kukui	Aleurites molucana
Milo	Thespesia populnea
Kamani	Calophyllum inophyllum
Kou	Cordia subcordata
Noni	Morinda citrifolia

Many native trees may have been substituted as raw material until these introduced trees become plentiful. Malo (1971) lists 23 other trees that were used by Hawaiians for such items as canoes, houses, canoe shelters, utensils, bowls, agricultural tools, bird catching tools, and fishing gear. I therefore suggest that the 'Initial Settlers' were not severely handicapped by the lack of forest products suitable as building materials.

AGRICULTURAL RESOURCES BROUGHT BY 'INITIAL SETTLEMENT GROUP'

Handy and Handy (1972) indicate that it would be unlikely that early colonizers would have brought all the plants and animals needed for permanent colonization, not only because of the difficulty in transporting such items, but also because of their inability to conceive of an area that did not contain the items they were accustomed to seeing as part of the landscape on adjacent or other visited islands. However, they do cite a reference to a group of four canoes that were stocked with plants and animals which had set off to find another homeland, and further, a reference to a group that had prepared several canoes in order to seek a new area for colonization due to strife at home (Porter 1822).

Another problem in determining which cultigens and animals might have been included in their cargo is the controversy which centers around which plants are native to Hawaii and would have been here prior to colonization. For purposes of this paper a list compiled by Gutmanis (1975) will be used (for details of these plants see Appendix).

CARGO LIMITATION OF DOUBLE CANOE

A very important factor in determining which cultigens and animals were brought with the 'Initial Settlement Group' is the limitation of cargo capacity on a double canoe. The Polynesian Voyaging Society has constructed a 60 foot double sailing canoe and for purposes of this presentation the displacement figure for this canoe, which is 24,000 pounds will be used (Finney private interview). After subtracting the weight of the canoe and gear, 10,000 pounds remain to be divided among occupants, food and water for voyage and cultigens and animals for colonization.

Hanna (private interview) indicated that the possibility of cold stress of Polynesian sailors may have induced natural selection for individuals with a great deal of subcutaneous fat which is clearly an important adaptational element for individuals who are chronically exposed to cold environments (LeBlanc 1954; Baker and Daniels 1956; Buskirk, Thomson and Whedon 1963). Although temperature ranges are quite moderate on most Polynesian Islands, this range drops drastically when at sea. Sailors are wet most of the time and are exposed to wind which causes a "chill factor" especially at night. Therefore, it is suggested that a 190 pound average weight would be probable for the male members of the crew and 130 pound average weight for the accompanying women. If there were 20 men and 5 women on this voyage (see pp. 83-87) their total weight would be 4,450 pounds.

If each man is alloted 2/3 of a gallon of water per day which is significantly less than the 7/8 of a gallon allotment which will be used for the Polynesian Voyaging Society's journey, and therefore, must be supplemented with rain water to ensure survival, and if the women and animals must split another two-thirds of a gallon a day, the total amount of displacement for water on a 35 day journey would be 4,620 pounds.

If each crew member is allowed 3/4 pound of dried fish and bananas, which would allow them a 1,481 calorie intake per day, and each woman is allowed the same ration, which must be shared with the animals, there is an additional 656 pounds of weight used for voyaging food.

Further, if 4 puppies, 4 piglets and 4 mature chickens are included in the cargo another 60 pounds is used for the animals and their pens.

This leaves only 214 pounds for cultigens and their packaging and the containers for food and water which will be consumed on the voyage. It reduces the 3,525 calories per day food intake computed by the Polynesian Voyaging Society to be necessary for their trip to a mere 1,481 calorie intake.

CULTIGENS

In view of the limited amount of weight available to be used for transporting cultigens I would suggest that these would be selected with the utmost care, and many plants that might not be considered 'critical' to the survival of the new colony would not be included in the cargo. Those plants propagated by seed would not have been a problem, but plants such as those propagated by tuber, root stocks or stems might add considerable weight, especially when considering the packaging necessary to protect them from salt air or water, plus the necessity of carrying water to keep them alive. For purposes of this presentation the following plants will be considered as critical to the survival of the group and therefore included in their cargo. Taro (*Colocasia esculenta*), banana (*Musa sapientum*), sweet potato (*Ipomea batatas*), coconut (*Cocos nucifera*) and kava (*Piper methysticum*). Although I do not consider the latter necessary for survival, it may have been included for other reasons, as well as bamboo (*Schizostachyum glaucifolium*) which would have been an important tool resource. It is interesting to note that the four major gods of the Hawaiian pantheon are associated with many of the presumed introduced cultigens (Handy and Handy 1972); this possibly could be a reflection of the differential survival of specific cultigens or may mirror the importance placed upon specific food plants which would have been carefully chosen due to the severe limitations of cargo weight.

ANIMALS

As stated above, I believe that only puppies and piglets would have been transported aboard a colonizing canoe due to the critical weight factor. However, the chance of small chickens being able to survive due to the cold factor would possibly have made it necessary to have transported mature chickens. Further, because dogs and pigs reach maturity within a short time, dogs being able to reproduce at 8 months with a gestation period of 63 days, and pigs being able to reproduce at about 7 months with a 112 day gestation, (Hall private interview) it would not have been necessary to transport fully mature livestock in order to have a fairly rapid supply of animal food.

INITIAL SETTLEMENT GROUP

It must be understood that any reconstruction of an 'Initial Settlement Group' for Hawaii must be hypothetical. However, in order to have a model upon which to test likely population growth and problems of survival the following group is suggested.

ORIGIN

The origin of the Hawaiians is unknown. In the early 1800's David Malo (1971), a Hawaiian scholar, posited that his ancestors came in small detachments from Tahiti having been forced to flee because of war and driven in this direction by wind and bad storms. He further believed that two way journeys between Hawaii and this original homeland were responsible for certain sociopolitical aspects of the government as well as components of Hawaiian technology and ecology.

Many early writers have argued that the early Polynesians did not have the technological expertise to cross vast areas of ocean and therefore, the settlement of the Polynesian Islands must have been due to accidental or one-way voyages (Wilson 1799; Jarves 1843). Sharp (1956) has rekindled this controversy and has been challenged by several researchers (Levison, et. al. 1972; Golson 1963; Finney 1967).

Another controversy has been centered around the homeland of the original settlers. Recent research based on tool types and glottochronology has suggested that this was the Marquesas rather than the Society Islands (Emory 1959, 1963; Emory, Bonk and Sinoto 1959; Emory and Sinoto 1964; Sinoto 1968). Finney (1967) indicates that in regard to winds and currents a Marquesan homeland for the Hawaiian immigrants would be possible, as a double sailing canoe of the Polynesian type could make this voyage, however, a return trip to the Marquesas would be improbable. The inability of the 'Initial Settlement Group' to return to their home base, for whatever reason, would make it necessary that they either included sufficient food, animals, and cultigens to ensure their survival in the new land or that they were resourceful enough to sufficiently exploit the new environment to accomplish the survival of the majority of their group.

NUMBER

As mentioned above (p. 78) early references indicate that Polynesian settlers had been known to voyage in groups of more than one canoe (Handy and Handy 1972; Porter 1822). A modern reference to canoes sailing in groups is cited by Gladwin (1970) for navigation within the Caroline Islands. Gladwin points out however, the extreme difficulty in canoes keeping in sight of each other, particularly at night, and once contact has been lost it is quite improbable that the canoes can rejoin at sea. Therefore, for purposes of this presentation it will be proposed that the 'Initial Settlement Group' that reaches Hawaii will be the occupants of only one canoe.

Finney (private interview) suggested that 20-25 people would be a reasonable number of occupants on a 60 foot double canoe for long distance traveling, which includes a crew of possibly 20 men, as is planned for the upcoming Polynesian Voyaging Society's experimental voyage to Tahiti.

The number of occupants on a canoe is primarily limited by the displacement weight of the ship and therefore, if many cultigens were being transported the number of occupants would have to be decreased, or if it was known that the voyage would continue over an extended period of time the number of occupants would have to be decreased due to the necessity of carrying enough food and water to sustain them for the duration of the voyage.

Realizing the number of occupants on a double canoe would be an extremely fluctuating variable, for purpose of this presentation it will include 25 adults.

SEX

Needless to say, an 'Initial Settlement Group' in order to set up a viable colony in a new homeland must include both men and women. Today, in areas where canoe voyaging is still practiced the presence of women on board involves not only making physical changes to the canoe, but also adds to the responsibilities of the crew members, as each woman must have a man who is willing to care for her needs during the complete voyage when she will be restricted to a small grass hut constructed on the canoe for this purpose (Gladwin 1970).

AGE

A further consideration is the age of the crew members and passengers. It was indicated by Captain David Lyman during a discussion group sponsored by the Polynesian Voyaging Society on October 12, 1975 at Kualoa Regional Park that in their research and training of possible members of the crew it was their experience that older men (25-35) reacted better in times of stress than did younger men, and therefore, many of their crew members would be selected from this age bracket. Based on the above research the male members of the model 'Initial Settlement Group' will be between the ages of 25-35. However, because the reproductive capacity of the females would possibly have been of major importance to this group, the women will be between the ages of 15-21.

NUTRITIONAL NEEDS

Again, this factor is one of great variability. The nutrients needed by both humans and animals are commonly grouped under the headings of: calories, proteins, minerals and vitamins. An adequate diet must include not only sufficient calories to furnish energy needs, but also enough proteins to supply the needed amino acids for growth and maintenance as well as sufficient amounts of all the required minerals and vitamins needed for good health. Recommended standards of these variables have been set forth by the National Food and Nutrition Council and are listed in Appendix C. However, recent research (Miller and Rivers 1972) indicates that chronic undernutrition, as defined by the standard tables, is not as pathological for some populations as has formerly been suggested. In their research the average caloric intake of Ethiopian male adults was 1,475 calories per day and the female intake was a considerably lower 950 calories per day. However, these extremely low caloric intakes were not associated with any catastrophic effects such as reduced ability to engage in physical work, declines in body weight, clinical signs of starvation, or high death rates. In addition to the above scientific research, the statements of many prisoners of war upon their return from captivity have attested to the fact that they were able to continue to engage in 'hard manual labor' even after several years of severely restricted diets and extreme weight loss.

For purposes of this presentation, the National Food and Nutrition Council's recommendations will be used as a standard against which to test possible nutritional resources; however, due to the findings of the above mentioned research these standards will not be considered as 'absolutes' when considering the possible survival of the 'Initial Settlement Group'.

MODEL

Based upon the above guidelines, the model that will be used to represent an 'Initial Settlement Group' for this presentation will consist of 20 men (20-35 years of age), five women (15-21 years of age) plus one nursing infant who was considered too young to leave at home. This infant did not survive the voyage due to cold stress (Little and Hochner 1973) and therefore, the 'Initial Settlement Group' when it reached Hawaii included only the adult members of the original 'group.'

It is further suggested that the 'group' left the Marquesas in a 60 foot double sailing canoe loaded with several cultigens of taro, banana, sweet potato, kava, bamboo and 4 sprouting coconuts. All of these cultigens were carefully wrapped against possible contamination by sea water, but storms at sea ruined all but three taro and four sweet potato plants, plus one remaining sprouted coconut.

In addition to the cultigens the following livestock was included as cargo: four puppies (two female and two male), four piglets (two female and two male) and four mature chickens (two female and two male). Adversity at sea killed several of the animals and the chickens were eaten by the crew, therefore the animal inventory was seriously depleted and only included two puppies (one female and one male) plus two piglets (one female and one male) when they arrived in Hawaii.

Having survived a serious storm at sea the 'Initial Settlement Group' lands in Hawaii with 20 men, two of whom are injured, (one so seriously that he dies during the first 6 months) and five women. Although all the group are suffering from lack of food and water, they are able to find enough wild foods and fish to regain their strength within a month and begin a search for a suitable area to colonize. After six weeks of exploring they determine that their original colony will begin in the proposed area of settlement (pp.60-65) and they begin their life in a new land after performing the required supernatural rituals.

POPULATION GROWTH MODEL

As stated above the model group contains 20 men (ages 20-35) and 5 women (ages 15-21) who left the Marquesas in search of a new land and after surviving a severe storm at sea arrive in Hawaii and begin to build a colony on the north windward coast of Oahu.

Upon reaching the new settlement area they realize that their success in coming years will depend upon the fertility of not only their few agricultural products, but also their population. Therefore, no birth control of any type is practiced, neither prolonged nursing of infants nor infanticide.

For purposes of this model three variables of fecundity will be used in a rotating manner. Each woman will give birth either on a cycle of one child every two, three or four years. A female child will be considered an adult and therefore a member of the breeding population at the age of 15 and women generally will bear children until their 45-55th year.

A 30% attrition rate will be used in regard to infant mortality. This figure is substantially less than the 50% usually used for modern primitive groups; but the modern groups are confronted with introduced European diseases and are often found in marginal environments. Dr. Tabrah (private interview) indicated that the incidence of disease in these islands would probably have been low prior to European contact and that the 30% attrition rate would be a reasonable one.

This model is based on the premise that although domesticated food resources would be low, especially during the first five years of occupancy, native foods would be adequate to support the growing population. Therefore, this model is designed on the premise that most variables work for the 'good' of the colony.

Within the first five years of the model one of the women will die in childbirth leaving no progeny, one of the men injured on the voyage will die shortly after arrival in Hawaii and a third man will be killed in a fight over the wife of the deceased crew member.

Therefore, the original colony is reduced within the first five year phase to include 18 men and 4 women, one of whom is barren.

Table 1 (p. 90) illustrates the population growth which might be expected based upon the above parameters in five year increments. Although the model set forth above includes only three child-bearing women, an alternate model with four child-bearing women is also included.

The fecundity rate is based on the fact that many modern Hawaiian families include mothers under the age of thirty who have borne ten to fourteen children.

Male/female rate of survival is calculated at 50:50, however, the model is slightly skewed in favor of female survival.

Although many variables might be considered that would alter the above proposed population growth, I believe the most crucial one would be an attempt for a portion of the group to return to their homeland.

It is probably most reasonable to assume that 20 men who left their homeland with only 5 women would expect that a portion of the group would either return to their home for additional women or that there might be women in their new area with which they could mate. Further, upon reaching an island of such outstanding beauty and colonizing potential there must have been a great desire among many of the men to return and tell their relatives about the area in order that they might join them. Also, Lewthwaite (1967:71) cites an early missionary's discussion about the high status enjoyed by men who had discovered new lands and this might have been an add-

TABLE 1

PHASE	TIME SPAN	3 Original Child-bearing Women	4 Original Child-bearing Women
		POPULATION	
1	(end of 5 years)	25	26
2	(end of 10 years)	29	32
3	(end of 15 years)	33	37
4	(end of 20 years)	40	46
5	(end of 25 years)	50	59
6	(end of 30 years)	63	77
7	(end of 35 years)	74	99
8	(end of 40 years)	86	119
9	(end of 45 years)	112	153
10	(end of 50 years)	142	199
Ratio of children to adults at end of 50 years		60:82	77:122

ed impetus to return. An additional reason might be the need to secure additional cultigens, for as mentioned above it is unlikely that they arrived in Hawaii with a complete inventory of plants they considered necessary for the 'good life'. Although from a modern technological view it is very unlikely they would have been able to sail home (Finney 1967:161), I suggest that they did not necessarily know this.

However, the most important issue in examining the possibility of their return home is not whether they had the desire to go, but rather, did they have the ability to attempt such a long and hazardous voyage. The following models are offered to examine this possibility.

MODEL 1 (Phase 3 - end of 15 years)

I believe it would have taken at least 15 years to have established their agriculture well enough to allow them to leave a small colony in Hawaii and gather enough provisions for the return voyage. They would also need the raw materials necessary to prepare their canoe for such a long journey; cordage for tying the boat together, material for a new sail, and some type of waterproofing for caulking the joints. It is possible that by this time they could have discovered the excellent cordage that could be provided by the native olonā tree (Touchardia latifolia) and therefore were not dependent upon the maturation of their coconut tree. It is also possible that they may have discovered the waterproofing properties of the Pisonia sandwicensis gum. If the hala (Pandanus odoratissimus) was a native tree or if they had brought seeds with them this might have provided the raw material for a new sail.

At the fifteen year mark the canoe must necessarily be manned by the original settlers, as the oldest male child would be less than 15 years old (See Appendix B). If the boat could be manned by 12 men then the population left at home, calculated on the foregoing Population Model, would be as follows:

MODEL 1

Population		Age (years)
6	Adult men	35-50
4	Adult females	30-36
3	Children (2 f. 1 m.)	10-15
4	Children (2 f. 2 m.)	5-10
4	Children (2 f. 2 m.)	0- 5
22		

A return journey at this time would severely limit the population left in Hawaii and might seriously have affected the future growth of the colony. However, if the agricultural products were producing well they were probably able to survive.

MODEL 2 (Phase 5 - end of 25 years)

If an attempt was made to return to the homeland at the end of 25 years with a short crew of 12 men, then 10 of the men would have to be drawn from the original group who at this time would be between the ages of 40-55 years old, possibly the maximum age at which they would be able to paddle for long periods of time if necessary. One young man would be from the 20-25 year old group which would have deprived this group of their only male member and one young man would be from the 15-20 year old group. Population left in Hawaii would be as follows:

MODEL 2

Population		Age (years)
8	Adult men	40-55
4	Adult women	35-41
2	Adult women	20-25
3	Adults (2 f. 1 m.)	15-20
4	Children (2 f. 1 m.)	10-15
7	Children (4 f. 3 m.)	5-10
10	Children (5 f. 5 m.)	0- 5
38		

The food production of the colony left in Hawaii would be seriously hampered by a voyage attempted at this time. The crew members drawn from the 'original settlers' would probably have to include the youngest men of this age group which would have left 8 men in their 50's, 4 women who are still child-bearing and between 35-41 years old, 2 females child-bearing between 20-25 years old, 2 females child-bearing between 15-20 years old plus one male 15-20 years old to produce not only enough food for themselves, but for 21 children as well. Another major consideration is that a voyage at this time would leave the colony with only one male child between 15 and 40 years.

MODEL 3 (Phase 8 - end of 40 years)

At this point in time there are finally enough young men to crew the canoe and the population left in Hawaii would be as follows:

MODEL 3

Population		Age (years)
8	Adult men	60-75
2	Adult women	55-61
2	Adult women	35-40
2	Adult women	30-35
2	Adult women	25-30
1	Adult man	25-30
4	Adult women	20-25
5	Adult women	15-20
13	Children (7 f. 6 m.)	10-15
16	Children (8 f. 8 m.)	5-10
18	Children (9 f. 9 m.)	0- 5
73		

As can be seen from the above, a return voyage would leave 8 adult men between the ages of 60-75 plus two adult women between the ages of 55-61 and 15 child-bearing women from 15-40 to feed themselves and 47 children. It would also necessitate taking one of the original men to serve as navigator or captain to show them the way home and he would be a minimum of 60 years old and may not have been able to survive the journey. In addition, of the 9 men left at home only one man is less than 60 years old which would not have been practical from the standpoint of either feeding or breeding the settlement population. A further factor that may have prevented a return trip at this time was the fact that the young men had made their life in the new homeland and the desire to return to the Marquesas might not have been very strong among the younger age groups. If they attempted this return I believe it would have been more in the spirit of adventure than for any other reason.

POSSIBLE PROBLEMS/SOLUTIONS

The possible problems encountered by an 'Initial Settlement Group' and the manner in which they solved them are multitudinous; and by their very nature conjectural. I believe however, that the most important of these was the requirement for adequate nutrition. Other problems might include those which were caused by the shortage of women, lack of older women to serve as midwives or baby sitters, lack of priests and healers to care for the spiritual and physical needs of the colonizers, and lack of raw materials for such items as canoe maintenance, utensils, and tools.

In regard to the manner in which they may have solved these problems it must be emphasized that although the 'model group' were members of an established Marquesan culture, they did not represent the corporate knowledge of the original culture and therefore, may not have possessed the knowledge to be Marquesan housebuilders, farmers, fishermen, adze makers, fishhook manufacturers, priests or healers, but rather, would at times need to improvise new ways to solve both technological and sociological demands.

It is with the above limitations in mind that I would like to set forth the following problems which may have confronted the 'Initial Settlement Group' as well as their possible solutions.

NUTRITION

As mentioned previously, an adequate diet must furnish sufficient calories to satisfy the body's energy requirements as well as sufficient protein, minerals and vitamins to promote growth and maintain good health. However, if the calories are sufficient to cover the energy requirements the body has the ability to adjust to low intakes of protein and other nutrients for short periods of time (Miller 1974:169). This adjustment factor would possibly be very important to the 'Initial Settlement Group' due to the shortage of a variety of foods during the voyage, as well as, for the first few months of colonization when caloric requirements could probably have been met but vitamin sources, which must be obtained from foods on a daily basis, might have been scarce.

After examining the possible native resources I propose that if the colonizing group had been aware of the nutrient value of just a few of the native resources they would have had a very adequate diet on which to subsist until their domesticated plants and animals produced in sufficient quantity to sustain the growing population.

To validate this statement I will set forth the various nutritional requirements as indicated by the National Food and Nutrition Council (Facts About Foods 1961), listed in Table 2 and possible Hawaiian native and domesticated resources which might have met these needs as compiled in Table 3.

TABLE 2

NUTRITIONAL REQUIREMENTS

	Calories	Protein	Calcium	Iron	VITAMIN A	VITAMIN B1	VITAMIN B2	VITAMIN Niacin	VITAMIN C
		gm.	gm.	mg.	I.U.	mg.	mg.	mg.	mg.
RECOMMENDED DAILY REQ.									
Women (16-19)	2400	75	1.3	15	5000	1.2	1.9	16	80
Men (25-45)	3200	70	.8	10	5000	1.6	1.8	21	75
Children (1-3) (27 pounds)	1300	40	1.0	7	2000	0.7	1.0	8	35
Children (4-6) (40 pounds)	1700	50	1.0	8	2500	0.9	1.3	11	50

(National Food and Nutrition Council)

TABLE 3

NUTRITIONAL VALUES OF HAWAIIAN FOODS
(Langworthy and Deuel 1922; ABC 1964; Miller 1927, 1929, 1952, 1974; Miller et al., 1944, 1956)

		Calories	Protein gm.	Calcium gm.	Iron mg.	VITAMIN A I.U.	VITAMIN B1 mg.	VITAMIN B2 mg.	VITAMIN Niacin mg.	VITAMIN C mg.
MEAT, POULTRY, FISH										
Aku 4(2½x1½x¼")		44								
Barracuda	4 oz.	100								
Bonita	4 oz.	150								
Chicken	3 oz.	170	25	12	1.5	0	.03	.14	5.4	0
Crab	3 oz.	90	14	38	.8	0	.04	.05	2.1	0
Duck	4 oz.	260								
Eel	4 oz.	185								
Limu		(Carbohydrate not digestible by man, inadequate source of vitamins)								
Lobster	4 oz.	100								
Mahimahi	4 oz.	110								
Opihi	100 gr.					4000				
Pork	3 oz.	285	20	9	2.6		.71	.20	4.3	0
Snapper (red)	4 oz.	100								
Squid	4 oz.	80								
Tuna	3 oz.	170	25	10	3.0	-0	.07	.24	5.2	0
FRUITS AND VEGETABLES										
Arrowroot flour	2 oz.	225								
Banana	1 med	100	1	8	.6	430	.04	.05	.7	10
Breadfruit	1 lb.	588				150				40
Coconut (2x1x½)		100								
Gourd	4 oz.	14								
Sweet Potato (5x2")		185	3	44	1.1		.12	.08	.9	28
Taro Leaves	16 oz.					130				40
Taro (4½ lbs.)	2000 gr.	2400					1.60	.56	10.0	
TREE FERN										
Hapu'u i'i starch	150 gr.	1990	23							

CALORIC REQUIREMENTS AND RESOURCES

Requirements

Women (16-19)	2400 calories per day
Women (25-45)	2300 calories per day
Women (pregnant)	2600 calories per day
Women (lactating)	3300 calories per day
Men (25-45)	3200 calories per day

Resources

Chicken	3½ lbs.	3200 calories
Duck	3 lbs.	3200 calories
Fish	8 lbs.	3200 calories
Hapu'u i'i (starch)	1/3 lb.	3200 calories
Taro	5 lbs.	2724 calories

As can be seen by the above, *Hapu'u i'i* tree fern (*Cibotium chamissoi (menziesii)*) could have been a very important source of calories for the 'Initial Settlers.' Although it would have required a good deal of energy expenditure to cut the large 50-75 pound trunks and transport them from the mountains to the living sites, I do not believe that it would have required as much energy as would have been necessary to gain the same amount of calories from fish or wild birds. It is unknown if the 'Initial Settlers' were aware of its food value, but it is listed as a famine food of the early Hawaiians by several researchers (Buck 1964; Handy and Handy 1972; Malo 1971) and other species of fern are present in the Marquesas and therefore the 'Initial Settlers' may have been aware that ferns did offer a food resource. Presently these ferns are available in the mountains included in the proposed area of settlement (Bryan n.d.).

PROTEIN REQUIREMENTS AND RESOURCES

Requirements

Women (16-19)	75 Grams per day
Women (25-45)	58 Grams per day
Women (pregnant)	78 Grams per day
Women (lactating)	98 Grams per day
Men (25-45)	70 Grams per day

Resources

Chicken	9 oz.	75 Grams
Fish (tuna)	9 oz.	75 Grams
Hapu'u i'i (starch)	16 oz.	77 Grams

Again it might be stated that *Hapu'u i'i* (*Cibotium chamissoi* (*menziesii*)) could have been an important food resource for the 'Initial Settlers.'

VITAMIN A REQUIREMENTS AND RESOURCES

Requirements

Women (16-45)	5000 I.U. units per day
Women (pregnant)	6000 I.U. units per day
Women (lactating)	8000 I.U. units per day
Men (25-45)	5000 I.U. units per day

Resources

Opihi	125 Grams	5000 I.U.
Organ meats	2 oz.	approx. 30,000 I.U.

The Hawaiian limpet *Opihi* is mentioned by several researchers as a basic food resource of ancient Hawaiians (Buck 1964; Handy and Handy 1972; Malo 1971) as well as being a popular modern shellfish. Today, these shellfish are still quite abundant on the margins of the Hauula coral reef and, as seen above, would be a major resource for Vitamin A (Miller and Robbins 1940).

THIAMINE (Vitamin B1) REQUIREMENTS AND RESOURCES

Requirements

Women (16-45)	1.2 mg. per day
Women (pregnant)	1.3 mg. per day
Women (lactating)	1.7 mg. per day
Men (25-45)	1.6 mg. per day

Resources

Pork	6 oz.	1.40 mg.
Sweet Potato	5 x 2"	.12 mg.
Taro	4½ lb.	1.60 mg.

RIBOFLAVIN (Vitamin B2) REQUIREMENTS AND RESOURCES

Requirements

Women (16-19)	1.9 mg. per day
Women (25-45)	1.5 mg. per day
Women (pregnant)	2.0 mg. per day
Women (lactating)	2.5 mg. per day
Men (25-45)	1.8 mg. per day

Resources

Organ meats	2 oz.	2.25 mg.
Taro	4½ lbs.	.56 mg.

As the Vitamin B data indicates, there may have been shortages of both Vitamin B1 and B2 for consumption by the 'Initial Settlement Group' during the period prior to domisticated plants and animals being available. However, it is possible that Hapu'u i'i (Cibotium chamissoi (menziesii)) could contain some of these vitamins, but no information is available regarding this plant's vitamin content at this time.

NIACIN REQUIREMENTS AND RESOURCES

Requirements

Women (16-19)		16 mg. per day
Women (25-45)		17 mg. per day
Women (pregnant)		20 mg. per day
Women (lactating)		21 mg. per day
Men (25-45)		21 mg. per day

Resources

Chicken	12 oz.	21 mg.
Fish (tuna)	6 oz.	21 mg.

VITAMIN C REQUIREMENTS AND RESOURCES

Requirements

Entire population	400 I.U. units per day

Resources

Most green leafy vegetables contain small quantities

Breadfruit	1 lb.	30 I.U.
Taro leaves	2 lbs.	80 I.U.

MINERAL REQUIREMENTS AND RESOURCES

The critical mineral requirements include calcium, iron, and iodine. All of these requirements are found in large amounts in fish and shellfish and therefore would have been available in sufficient quantities for the 'Initial Settlement Group'.

As can be seen above, sufficient nutrients were available in native resources to sustain the 'group' if only a few of them were exploited. The only nutritional problems that may have been present would possibly have been low quantities of Vitamins B1, B2 and C. However, because of the ability of the human to adjust to vitamin deficiences for short periods of time, I do not believe that the

'Initial Settlers' were unable to survive and continue as a viable colony.

SHORTAGE OF MATES

It would be reasonable to assume that there could have been serious social consequences due to the lack of appropriate mates for the majority of the men in the 'group'. Because no reference to polyandry has been found in my research, I will delete this alternative as a solution to this problem. Other solutions may have been a lack of punishment for extra-marital sexual relations and rather, an emphasis on the biological perpetuation of the group. This attitude may have been mirrored in the description of some of the early missionaries who indicated that the Hawaiians were sexually indiscriminate (Ellis 1963). Another solution may have been a stratification of society, whereby some men were held in such esteem that none of their possessions (including women) could be violated without serious repercussions. This solution may be one of the many causes for the extremely stratified society usually associated with early Hawaiian Society (Malo 1971; Handy and Handy 1972).

SHORTAGE OF OLDER WOMEN

The problem of the shortage of older women to function as midwives and baby sitters is established in the 'Model Group' by the loss of one of the women in childbirth. In this 'group' most of the women are very young when they leave the Marquesas and it would be very unlikely that many of them would have been greatly skilled in aiding during childbirth. This could have had serious consequences to the colony if a large percentage of the women had difficult labors which caused either their own or their child's death. However, none of my research has indicated that severe labor problems in childbirth existed in Hawaii and therefore I do not see it as a serious handicap to the 'group' in their survival effort.

In regard to the lack of baby sitters, there probably was more inconvenience than actual danger associated with the lack of tutus. Women in many primitive societies take their infants with them when gathering food or working in the fields; in Hawaii with its mild temperatures and lack of dangerous animals there probably would have been no disadvantage in caring for an infant while working, other than possibly the nuisance factor.

LACK OF PRIESTS AND HEALERS

It would seem reasonable if a population believed that only a priest could make intercessions in their behalf with the supernatural that it would be improbable that they would have the confidence to journey to a new land and attempt to begin a new colony without being accompanied by a priest. However, the early Hawaiians do not seem to have had this problem. Malo (1971) indicates that the manner of worship of the kings or chiefs differed from those of the common people and only the 'high born' required the services of the priest. When the common man wished to worship he was able not only to offer the prayers himself, but was also, capable of performing many of the rituals associated with various rites. And yet, many social and personal enterprises appear to have required a priest in attendance; the building of a new canoe, the healing of the sick, the subincision of a male child, the building of a heiau, plus any corporate worship of the gods of the fishermen and farmers. Perhaps what is reflected in Hawaii is the similar circumstances of the early American pioneers where rites considered extremely important such as baptism, marriage and death memorials were placed in abeyance until such time as a clergyman was available to perform them. Therefore, if a priest did not accompany them the 'Initial Settlers' may have believed they could return to their homeland, once they established a new colony, and persuade a priest to join them, at which time the necessary rites would have been performed.

As mentioned by Malo (1971) the medical treatment of the ill was also a matter which belonged to the worship of the gods and required a priest as healer. However, if the 'group' were forced to leave their homeland due to some dire disaster, the prospects of sailing off without a healer to care for a possible illness in the future may have seemed the lesser of two evils if they faced sure death at home either due to famine or warfare.

LACK OF RAW MATERIALS

As mentioned earlier, the colonizers would have needed many plant products to serve as raw materials for such items as houses, canoe sheds, clothing, baskets, bowls, knives, utensils, agricultural tools, fishing gear and of great importance materials required to maintain and repair their canoe. Many of these raw materials may not have been available to the 'Initial Settlers' particularly if they had been brought to Hawaii as cultigens by the settlement group. It would therefore be necessary for the colonizers to substitute other plant products until such time as their cultigens would have reproduced in sufficient quantity to be used.

Although it is not within the scope of this paper to examine all the possible substitutes, I would like to mention a few which I believe may have had serious consequences to the survival of the 'group.'

CANOE MAINTENANCE AND REPAIR

The primary raw materials needed for the maintenance and repair of their canoe which might not have been present during early colonization were waterproof caulking, cordage material and sail material. At European contact these materials were gathered from the breadfruit (_Artocarpus aetilis_), coconut (_cocus nucifera_) and _hala_ (_Pandanus odoratissimus_) trees respectively. As mentioned earlier (pp. 75-78), two plants may have been used as substitutes for breadfruit gum, _Pisonia sandwicensis_ and _'oha-kepau_ (_Cyanea solanacea_) each of which are mentioned by early researchers (Cook 1967; Malo 1971) to be valued for their sticky gum. A possible substitute for the presumed lack of coconut husks for cordage would be the native Hawaiian shrub (Fosberg 1948) _olonā_ which is mentioned by both Malo (1971) and Handy and Handy (1972), who state that the cordage produced from this shrub was superior to that produced by coconut sennit. Buck (1964) also mentions two other Hawaiian native plants which were used for cordage in the context of raw material for houses, _'uki 'uki_ and _'ie 'ie_ (_Freycinetia arborea_). Although I have spent a great deal of time in research regarding the problem of a substitute for _hala_ (_Pandanus odoratissimus_) as a raw material for sails, no substitute could be located. I would like to suggest that if no raw material was available for this requirement that possibly the double canoe was dismantled and the hulls used to make two outrigger canoes which would have been easier to man by paddling and would have given them an additional fishing vessel.

LACK OF BAMBOO FOR CUTTING INSTRUMENTS

If bamboo (Schizostachyum glauchifolium) was an introduced plant (Krauss 1972), then it would have been some time before it could have been used to produce knives or cutting instruments. I would suggest that either sea shells or volcanic glass could have been substituted for this raw material.

LACK OF MANUFACTURING AND CONSTRUCTION MATERIALS

Because Hawaii has many native trees which may have substituted for raw materials needed in construction of houses and canoe sheds as well as many hard woods useful in the manufacture of tools, bowls and utensils, I do not believe that this presented any problem for the colonizers, but merely was a matter of determining which resource was best for each need. It also should be mentioned that at least one native Hawaiian tree the koa (Acacia koa) which is found nowhere else in Polynesia (Handy and Handy 1972) is an excellent wood for canoes and once its outstanding properties were discovered was possibly extensively exploited.

ARCHAEOLOGICAL DATA

Because the Proposed Area of Initial Settlement is a somewhat different concept of environmental exploitation in Hawaii than has been formerly investigated there is no matching archaeological data with which it might be compared. Further, no site has yet been excavated in Hawaii that has been classified as the Original Settlement. Therefore, this presentation will be limited to examining the earliest prehistoric site in Hawaii and one which may have been a broadening exploitation of resources from an initial settlement in the Kailua-Kaimuki area (Tuggle private interview).

This site is located on the south windward coast of Oahu and is designated as Bellows Site 0-18. It is situated on a coastal sand dune near a fresh water stream with marine and littoral resource areas close by. This site was initially excavated in 1967 (Pearson, Kirch and Pietrusewsky 1971) with a second phase completed during the summer field season of 1975.

The site is composed of three distinct prehistoric occupation levels separated by sterile sand which were dated by hydration-rind analysis to represent the following time periods (Kirch 1974).

LAYER	MEAN DATE
I	A.D. 885
II	761
IIa	618
III	323

As noted above, three layers of occupation have been delineated within this site, however, because this presentation is concerned with 'initial settlement' only the first two layers (IIa and III) will be considered.

LAYER III

The oldest of these layers contained several features which include: a small imu, the burial of an old female, several small pits, an area containing basaltic debitage, and a localized area of small water-washed stones with associated post molds which was originally interpreted to represent a rectangular structure (Pearson, Kirch and Pietrusewsky 1971), but subsequently has been reinterpreted to represent an oval-ended pole-thatch dwelling structure (Kirch 1974).

Also included within this layer were a number of artifacts: several fishhooks, a grater, a scraper, adze and adze fragments, abraders, a coral rubbing stone, a lithic drill, one imitation porpoise tooth ornament made of mammal bone and 9 pieces of volcanic glass (Pearson, Kirch and Pietrusewsky 1971). An additional artifact within this layer was a piece of cut mammal bone (Kirch private interview).

The midden within this earliest zone of occupation included several species of fish and shellfish, however, no information has been published that indicates the presence of bird, dog, or pig bone midden within this stratum.

LAYER IIa

The next occupational zone had a mean time date of 618 A.D. which is 295 years later than the original occupation represented by Layer III and included the following features: a fire pit, four charcoal lenses and four burials which were excavated. Within the burials are representatives of an adult man, an old woman, a 1-1½ year old infant and a nine year old female child. The burial of the young girl was extremely elaborate; the sand around the body was colored red possibly by either the presence of ochre or the body may have been wrapped in colored bark cloth which may have produced the stain. Included within this burial was a stone knife, as well as an ornament made of rock oyster shell (classified as a niho palaoa) which was found lying on the chest and in additon encircling the left leg was an anklet made of 23 pieces of worked and drilled boar tusk.

The additional artifacts associated with this stratum include: 15 fishhooks, adze and adze fragments, abraders, a rubbing stone, a drill, chisels, cut bone and shell pieces, as well as 200 flakes of volcanic glass (some with bulbs of persussion), and an unknown quantity of basalt flakes.

The midden for this layer includes not only the species of fish and shellfish represented in the earlier occupation, but also includes other fish species as well as additonal faunal material such as pig, dog and bird bone.

The excavators of Bellows 0-18 (Pearson, Kirch and Pietrusewsky 1971; Kirch 1974, ms.) infer from the above research that an adaptation to the Hawaiian environment was taking place at this site, possibly from a Marquesan origin. They also suggest that it represents a permanent sedentary settlement of people who are exploiting many of the microenvironments of the area including: open sea, offshore islands, inshore regions, littoral zones, strand, stream valley floor, upland and rock outcrops. And further, that social differentiation, similar to that known from ethnographic accounts, is evidenced by the elaborate burial of the young girl. I would suggest that another interpretation of this burial may be that it reflects the great sorrow which often accompanies the death of a young child, especially in cultures where they are considered a valuable asset to the group.

The lack of evidence of either pig, dog or bird remains as a food resource in Layer III may be significant to the understanding of the importance of these foods to the early Hawaiian populations. The lack of these species may be due to sampling error, but also may indicate that they were not considered as a food resource until the time period represented by Layer II. The time period of this later stratum is also evident at the Halawa, Molokai site which included house features similar to those found at Bellows as well as pig and dog remains, however, bird bones do not appear at this site until a later date (Griffin et al. 1971; Riley 1973; Kirch 1970, 1971, 1974).

CONCLUSIONS

In conclusion, I would like to briefly summarize the information that has been presented, discuss how archaeological testing of the proposed settlement area may verify some of the suggestions set forth throughout the presentation and discuss some of the limitations of this research.

An Area of Settlement which extends from Kaiaipaloa Point to Laie Bay has been proposed for the initial settlement of Hawaii that differs from both Cordy's (1974) and Newman's (1969) models. This proposed area would have included optimal microenvironments for a variety of native resources: fresh water, bird, deep sea and littoral marine resources, as well as vegetable resources from the plains, uplands and mountains. In addition, this area would also have furnished prime microenvironments suitable for both wet and dry agricultural crops possibly brought with the 'Initial Settlers' from their homeland.

In determining the chances of survival of an 'Initial Settlement Group' in the proposed ecobelt the various native resources which may have been present when they arrived have been examined. Several possible resources have been eliminated from consideration due to modern controversy centered around whether or not they represent actual pre-Polynesian contact species. This group includes taro (Colocasia esculenta), sweet potato (Ipomea batatus), coconut (Cocus nucifera), hala (Pandanus odoratissimus) and ti (Cordyline terminalis) all of which were of major importance to the Hawaiian culture when first visited by European explorers.

After an in-depth analysis of the remaining possible native plant resources it was suggested that although other researchers (Zimmerman 1963; Newman 1972) have discounted the importance of these resources to an 'Initial Settlement Group', that one native plant hapu'u i'i (Ciborium chamissoi), which is found not only within the proposed area of settlement, but also throughout the Hawaiian Islands in mountain regions, could have been of major importance to the survival of the 'Initial Settlers' because 8 pounds of fish or 5 pounds of taro would have to be injested to equal the available energy value offered by 1/3 of a pound of this tree fern starch. It was also posited that the 'Initial Settlers' may have been aware of the food value of other species of ferns as they are represented in the flora of the Marquesas Islands. It has also been indicated that sufficient plant resources were present from which the 'Initial

Settlers' could have chosen raw materials for construction of shelters and utensils, as well as materials necessary for the maintenance of their canoe which would have required the substitution of the native plants Pisonia sandwicensis and 'ohakepau (Cyanea solanacea) as a source of caulking and glue, and olona (Touchardia latifolia), 'uki 'uki and 'ie 'ie (Freycinetia arborea) as a source of cordage. However, an alternate to the hala (Pandanus odoratissimus) for raw material for sails was not located in the literature.

An analysis of Marquesan resources which might have been included as cargo on the colonizing canoe was then made and it was determined that the presence of cultigens and livestock would be severely limited due to the requirements of carrying sufficient food and water for survival during the journey, and therefore probably did not include more than 2 or 3 different species in addition to those propagated by seed. It was also posited that only immature livestock would have been transported due to the critical weight factor.

An abstract 'Initial Settlement Group' was constructed which included 20 adult men, ages 25-35, and 5 adult women, ages 15-21, who arrived in Hawaii after sailing from the Marquesas with two dogs, two piglets, a number of plant seeds, plus 3 taro and 4 sweet potato cultigens which had survived the voyage. I would like to suggest also that if 25 people attempted this voyage it would have been an extremely dangerous journey, if for no other reason than to place 25 occupants aboard a 60 foot double hulled canoe for 35 days would necessitate the water rations being limited to 2/3 of a gallon per day, which is significantly less than the 7/8 of a gallon which will be alloted to the Polynesian Voyaging Society's crew and food allowances must be dropped from their 3,525 calories per day to a mere 1,481 calories intake. I therefore suggest that a more reasonable number of occupants for a 35 day voyage would be 12 men and 4 women.

Population growth models were then analysed for the 'Initial Settlement Group' and it was suggested that an attempt to return to their homeland would probably have seriously affected the Hawaiian colony.

Possible problems encountered by the group were then discussed and it was posited that sufficient nutritional resources were available in the proposed area of settlement to sustain the group indefinitely until their livestock and cultigens were producing in sufficient quantities to support the geometrically increasing population. Further problems involving social adjustments were then discussed and possible solutions of highly conjectural nature were suggested, as well as possible alternatives to more concrete problems.

The archaeological data from a similar environmental zone, Bellows Site 0-18 were examined and although this site is not considered an 'initial settlement' it is the earliest thus far excavated in Hawaii and therefore is the closest representative of initial adaptation that could be examined. The research from this site indicates that a large range of ecological zones were being exploited by these early inhabitants and is therefore consistent with the adaptation posited for the 'Initial Settlers' of this model. The lack of evidence of bird, dog or pig as food resources within this site is only partially consistent with this model, as bird resources are posited to be a possible major food source for the 'Initial Settlers.'

Although, as indicated above, I believe that it was possible for an 'Initial Settlement Group' to sustain a viable colony in Hawaii, there are many variables that may have caused their demise. It is possible that they were unable to find social solutions to the lack of women as mates for the majority of their male members. This may have caused severe intragroup fighting that resulted in the colony being numerically depleted to the point where they were no longer able to sustain a population growth large enough to support the colony. Or it is possible that they were not resourceful enough to exploit the available native resources until their domesticated plants and animals matured and could support the group.

I would therefore like to suggest that due to the many microenvironments in the proposed area and the possibility that this area could have supported an 'Initial Settlement Group' that archaeological testing should be initiated as soon as possible, as this area is just now beginning to be extensively developed and within a short period of time much of the possible data could be destroyed.

Further, I would predict that such archaeological examination would indicate small sedentary nuclear groups living between the ocean and the swamp lands of the proposed settlement area (mosquitos were not introduced into Hawaii until 1826 and therefore would not have been a problem in regard to this settlement area (Van Dine 1904). That exploitation of a wide diversity of microenvironments would be indicated by the archaeological data with an early emphasis on deep sea marine resources the importance of which would be replaced through time by inshore marine exploitation. Further, if the 'group' had discovered the food value of the hapu'u i'i (Cibotium chamissoi) this would be reflected by the presence of earth ovens of sufficient size to bake the 50-75 pound trunks. A change through time within the agricultural areas may also be indicated by deforestation and charcoal deposits over wide areas which were subsequently utilized for domisticated crops or swamps may be replaced with irrigated taro patches. I further propose that even if features usually associated with social stratification are absent, such as large irrigation projects or fishponds; that social stratification may still be apparent in differential burials and could have possibly been a social solution to the problem of intragroup fighting due to the lack of a sufficient number of women as mates for the majority of the men.

Although verification of many of the suggestions set forth in this presentation is severely limited by the conjectural nature of the research, and the fact that much of the evidence in the proposed area of settlement may already be irretrievable, I do wish to emphasize that the ecobelt proposed does not necessarily have to be limited to this specific geographical area, but rather similar ecobelts may exist in the Hawaiian Chain which have not been destroyed by subsequent modern development and therefore may indicate that neither a 'wet/windward, stream leeward' (Cordy 1974) or a dry 'leeward' (Newman 1969) environment was chosen as an 'Initial Settlement Area' but rather, the first colonizers searched for a less specialized ecobelt that encompassed microenvironments usually associated with both of these areas.

I would like to state that information regarding the Hawaiian tree fern hapu'u i'i (*Cibotium chamissoi*) should be investigated more thoroughly, the vitamin and mineral content should particularly be determined. For although I have located nothing in the literature which indicates this plant was important to the early Hawaiians, if it contains as large an amount of vitamins and minerals as it does energy value, and if it could be dried to prevent decomposition, it may have been a primary voyaging food once the Hawaiian colonies were established well enough for subsequent long distance voyaging to be a possible alternative to complete isolation.

Appendix A

POSSIBLE INTRODUCED RESOURCES

ARROWROOT Pia (Tacca pinnatifida) (Tacca hawaiiensis)

Propagation:	Tubers
Area:	Low altitudes, open woods near water, wet taro patch banks (Krauss 1972).
Planted:	During February and March in uplands (Taylor 1969). Beginning of summer in lowlands (Handy and Handy 1972).
Maturation:	One year (Taylor 1969).
V/M/C	Arrowroot flour has caloric content of 225 calories per 2 oz. (ABC 1964).

BAMBOO Ohe (Schizostachyum glaucifolium)

Propagation:	Root sprouts
Area:	Lower wet forest areas.

BANANA Mai'a (Musa sapientum)

Propagation:	Root suckers. Pope (1926) states that partially dried rhizomes are very adaptible to long distance travel.
Area:	Higher mountain gorges and lower valleys (Pope 1926).
Maturation:	Twelve-fourteen months (Pope 1926). Harvested in uplands in February and March (Taylor 1969).
V/M/C	One medium banana contains 100 calories and is mostly carbohydrate (Farnsworth 1975). Bananas contain small amounts of Vitamin C (Miller 1974; Potgieter and Miller 1940). Contain large amounts of Vitamin A (Miller, et. al. 1947).

Note: V/M/C Vitamin, mineral and caloric content.

Banana Continued

Note:	One species propagates from seed and may have been introduced by birds (Handy and Handy 1972).

BREADFRUIT 'ulu (Artocarpus incisus) (Artocarpus aetilis)

Propagation:	Root shoots
Area:	Hot moist areas (Krauss 1972). Handy and Handy (1972) state must not be planted in sand or ash. Author has gigantic breadfruit tree which is planted in pure sand one block from beach.
Maturation:	Bears 5-7 years after planting root shoot (Krauss 1972). In Hawaii fruit ripens June to August (Krauss 1972). Author's tree bears from June through November and again from February through April.
V/M/C	Carbohydrate food low in protein and fat; however contains enough thiamine to aid in metabolism of carbohydrates, and is a fair source of Vitamin A (Miller, et. al. 1947; Miller 1974). Caloric value ½ cup pulp contains 147 calories (Farnsworth 1975).
Medical Use:	Latex for skin diseases, leaf buds for thrush.

CANDLENUT kukui (Aleurites molucana)

Propagation:	Seeds or seedlings (Gutmanis 1975). Seed is not salt resistant and does not float, therefore introduced by man (Handy and Handy 1972). Rock (1974) considers this tree to be native and indigenous.
Medical Use:	Juice of inner bark for sore throat, nut used raw as cathartic, leaves and rind of nut used as poultice.

COCONUT niu (Cocos nucifera)

Propagation:	Sprouted nut
Area:	Principally near beaches.
Maturation:	Plants begin to bear from 6-10 years after planting and will continue to bear up to age 100 (Krauss 1972). One tree may bear up to 50 nuts per year (Kennedy 1968).

Coconut Continued

V/M/C — Coconut water has a high calcium content but very little Vitamin A or B. Immature (spoon) coconuts have a small amount of Vitamin C (Miller 1929).

ELEPHANT EAR _'ape_ (_Alocasia macrorrhiza_)

Propagation: Tuber

Area: Small patches of dry land in the mountains.

Note: Used as famine food after thorough cooking (Neal 1948). Corm contains excessive concentrations of calcium oxide crystals (Handy and Handy 1972).

GINGER _Awapuhi kuahiwa_ (_Zingiber zerumbet_)

Propagation: Root

Area: Lower parts of damp open forest (Neal 1948).

GOURD _Ipu_ (_Lagenaria siceraria_)

Propagation: Seed

Area: Dry areas

V/M/C — Small amounts of Vitamin C (Miller, et. al. 1947). Caloric value 1 cup 28 calories (Farnsworth, personal interview).

Note: One type _ipu-'awa'awa_ was used for containers and medicine only. The second type _ipu-manalo_ was utilized for food also (Krauss 1972).

HAU (_Hibiscus tiliaceus_)

Propagation: Stem cuttings

Medical use: Leaves and sap as laxative.

KAVA (_Piper methysticum_)

Propagation: Stem cuttings

Area: Constant moisture and not much sun (Krauss 1972).

Kava Continued

Medical Use: Liquid congestion of urinary track, rheumatism; leaf, poultice for headaches.

KOU (*Cordia subcordata*)

Propagation: Seed

Area: Seashore and lowlands (Krauss 1972) hot areas (Handy and Handy 1972).

Medical Use: Treatment of thrush.

MILO (*Thespesia populnea*)

Propagation: Seed

Area: Planted near houses for shade.

Medical Use: Leaves were used for unknown purpose.

MOUNTAIN APPLE Ohi 'a-'ai (*Eugenia malaccensis*)

Propagation: Seed or seedling

Area: Shaded valleys to altitudes of 1,800 feet.

Maturation: Bears when seven or eight years old (Neal 1948). Ripens between July and August (Taylor 1969).

V/M/C Contains small portions of Vitamins B1 and C (Miller, et. al. 1947) (Miller 1974). Caloric value, one fruit contains 17 calories (Farnsworth, personal interview).

NONI (*Morinda citrifolia*)

Propagation: Seed or root sprout

Area: Open woodlands or lowlands.

Medical Use: Leaves and bark as tonic, fruit as poultice, juice to rid head of lice.

PAPER MULBERRY Wauke (*Broussonetia papyrifera*)

Propagation: Root sprouts (Gutmanis 1975). Shoots, slips and roots (Krauss 1972).

Paper Mulberry Continued

Area:	Along streams, in woods, hollows or uneven ground. Must be protected from winds (Krauss 1972).
Planted:	At end of summer.
Maturation:	Eighteen months
Medical Use:	Preparation used for treatment of thrush and as a laxative as well as containing 'magical' properties (Krauss 1972).

SUGAR CANE Ko (Saccharum officinarum)

Propagation:	Upper stalk cutting
Area:	Upper limits of growth on windward coast at altitudes of 1,800 and leeward or southerly slopes about 2,800 feet. Planted on banks of taro patches and lower forest zones as hedges or windbreaks.
Planted:	November and December.
Maturation:	1 year
V/M/C	No measurable quantities of Vitamin A, B or C (Miller 1929). One foot of cane yields 35 grams or 144 calories.

SWEET POTATO U'ala (Ipomea batatas)

Propagation:	Slips or stem cuttings (Gutmanis 1975), originally may have been propagated by seed (Handy and Handy 1972).
Area:	Varied with locality and variety. In dry areas after first winter rains, windward areas late winter, in wet areas after rainy season (Krauss 1972). February and March in lowlands and late March and April in uplands (Taylor 1969).
Maturation:	Greens available during April and May. Maturation of tubers from 3-7 months after planting slip. Never dug out completely only enough for current use.
V/M/C	Caloric value 185 (5"x2" potato). Protein 3 grams, Calcium 44 mg., Iron 1.1 mg., Sodium

Sweet Potato Continued

V/M/C cont.	5 mg., Vitamin A 11,410 I.U., Thiamin .12 mg., Riboflavin .08 mg., Niacin .9 mg., Vitamin C 28 mg. (Facts About Food 1961). Presence of Vitamin C in sweet potato is determined by depth of color. Most Hawaiian sweet potatoes were not deeply pigmented and would not be as good a source of Vitamin A as Taro tops (Miller 1974).
Medical Use:	Used to cure asthma, as a laxative and a liquid made from sweet potato was used to dislodge phlegm in throat.
Enemies:	Cutworms, weevils, caterpillars, rats and rooting animals.

TARO <u>Kalo</u> (<u>Colocasia antiquorum</u>) (<u>Colocasia esculenta</u>)

Propagation:	Huli (top of tuber plus about 6" of leaf stem) (Neal 1948).
Area:	Dry taro grown in rain-watered uplands without further irrigation. Wet taro is planted along streams, in marshy land irrigated by streams or in artificial terraces which are kept flooded with slow moving water a few inches deep (Neal 1948).
Planted:	In lowlands during February and March (Taylor 1969).
Maturation:	Some species mature between 6-12 months and the corm is harvested at that time, however, taro leaves are available prior to maturation of corm.
V/M/C	Caloric value; Taro (luaü) leaves ½ cup 35, <u>Poi</u> ½ cup 81. Sufficient taro to supply 2,400 calories would weigh less than five pounds and would furnish 1.6 mg. thiamin, .56 mg. riboflavin and 10 mg. niacin. This quantity would be an adequate source of thiamin but would furnish only 1/3 the riboflavin and ½ the niacin needed to meet allowances set forth by the National Research Council for nutritional intake (Miller 1952). Taro leaves are an important source of Vitamin A and add enough Vitamin B to aid in the metabolism of carbohydrates. Poi furnishes the organic acids which are usually supplied by fruits in the diet and also Vitamin C which is rather low but sufficient to be of value in

Taro Continued

V/M/C cont. preventing human scurvy (Miller 1929).

Enemies: Primary problems of growing taro is root rot, it is unknown exactly what causes this condition but is considered to be either bacterial or caused by fungus (Handy and Handy 1972).

<u>TI</u> (<u>Cordyline terminalis</u>) (<u>Taetsia fructicosa</u>)

Propagation: Stem cuttings

Area: Wetter open forests at lower elevations and along banks of taro patches (Krauss 1972).

Note: Single plant may produce a root weighing as much as 300 pounds (Neal 1948).

TURMERIC <u>Olena</u> (<u>Curcuma domestia</u>)

Propagation: Root tuber

Area: Damp forested valleys (Neal 1948).

Medical Use: Used to cure consumptives and to relieve ear-aches (Neal 1948).

WATERCRESS <u>Pa 'ihi</u> (<u>Nasturtium sarmentosum</u>)

Propagation: Transplant small plants

Area: Creeps on damp earth or floats in streams.

Medical Use: Used as unknown remedy (Gutmanis 1975).

YAM <u>Uhi</u> (<u>Dioscorea alata</u>)

Propagation: Tuber (Gutmanis 1975) seed tubers, or pieces of top of mature yam having 'eyes' or sprouts (Krauss 1972).

Area: Wet gulches and forests where trunks and branches of trees serve as supports for vines. Planted in inland gulches or semi-forested "<u>kula</u>" slopes, and lower zones of rain forests (Krauss 1972).

Planted: February and March in uplands (Taylor 1969) April through May (Handy and Handy 1972).

Yam Continued

Maturation:	One year for tuber to mature, however leaves are available as food within 8 months of planting. Tubers are harvested from November-March.
V/M/C	No available information on Hawaiian yams, however caloric value of mainland yam is 185 calories per 6 oz.
Medical Use:	Remedy for coughs, constipation, appendicitis, apolexy, dysentary and vomiting of blood.

Appendix B

POPULATION GROWTH MODELS

PHASE 1 (end of 5 years)

Population		Age (years)
18	Adult males	20-35
4	Adult females	15-21
3	Children (2 f. 1 m.)	0- 5
25		

PHASE 2 (end of 10 years)

Population		Age (years)
18	Adult males	25-40
4	Adult females	20-26
3	Children (2 f. 1 m.)	5-10
4	Children (2 f. 2 m.)	0- 5
29		

PHASE 3 (end of 15 years)

Population		Age (years)
18	Adult males	30-45
4	Adult females	25-31
3	Children (2 f. 1 m.)	10-15
4	Children (2 f. 2 m.)	5-10
4	Children (2 f. 2 m.)	0- 5
33		

PHASE 4 (end of 20 years)

Population		Age (years)
18	Adult males	35-50
4	Adult females	30-36
3	Adults (2 f. 1 m.)	15-20
4	Children (2 f. 2 m.)	10-15
4	Children (2 f. 2 m.)	5-10
7	Children (4 f. 3 m.)	0- 5
40		

PHASE 5 (end of 25 years)

Population		Age (years)
18	Adults males	40-55
4	Adult females	35-41
3	Adults (2 f. 1 m.)	20-25
4	Adults (2 f. 2 m.)	15-20
4	Children (2 f. 2 m.)	10-15
7	Children (4 f. 3 m.)	5-10
10	Children (5 f. 5 m.)	0- 5
50		

PHASE 6 (end of 30 years)

Population		Age (years)
18	Adult males	45-60
4	Adult females	40-46
3	Adults (2 f. 1 m.)	25-30
4	Adults (2 f. 2 m.)	20-25
4	Adults (2 f. 2 m.)	15-20
7	Children (4 f. 3 m.)	10-15
10	Children (5 f. 5 m.)	5-10
13	Children (7 f. 6 m.)	0- 0
63		

PHASE 7 (end of 35 years)

Population		Age (years)
13*	Adult males	55-70
4	Adult females	50-56
3	Adults (2 f. 1 m.)	30-35
4	Adults (2 f. 2 m.)	25-30
4	Adults (2 f. 2 m.)	20-25
7	Adults (4 f. 3 m.)	15-20
10	Children (5 f. 5 m.)	10-15
13	Children (7 f. 6 m.)	5-10
16	Children (8 f. 8 m.)	0- 5
74		

* 5 males of the original settlement group die during this time.

PHASE 8 (end of 40 years)

Population		Age (years)
9**	Adult males	60-75
2***	Adult females	55-61
3	Adults (2 f. 1 m.)	35-40
4	Adults (2 f. 2 m.)	30-35
4	Adults (2 f. 2 m.)	25-30
7	Adults (4 f. 3 m.)	20-25
10	Adults (5 f. 5 m.)	15-20
13	Children (7 f. 6 m.)	10-15
16	Children (8 f. 8 m.)	5-10
18	Children (9 f. 9 m.)	0- 5
86		

**4 males of original settlement group die during this time.

***2 females of original settlement group die during this time.

PHASE 9 (end of 45 years)

Population		Age (years)
6*	Adult males	65-80
2	Adult females	60-66
3	Adults (2 f. 1 m.)	40-45
4	Adults (2 f. 2 m.)	35-40
4	Adults (2 f. 2 m.)	30-35
7	Adults (4 f. 3 m.)	25-30
10	Adults (5 f. 5 m.)	20-25
13	Adults (7 f. 6 m.)	15-20
16	Children (8 f. 8 m.)	10-15
18	Children (9 f. 9 m.)	5-10
29	Children (15 f. 14 m.)	0- 5
112		

* 3 males of original settlement group die during this time.

PHASE 10 (end of 50 years)

Population		Age (years)
2*	Adult males	70-85
1**	Adult females	65-71
3	Adults (2 f. 1 m.)	45-50
4	Adults (2 f. 2 m.)	40-45
4	Adults (2 f. 2 m.)	35-40
7	Adults (4 f. 3 m.)	30-35
10	Adults (5 f. 5 m.)	25-30
13	Adults (7 f. 6 m.)	20-25
16	Adults (8 f. 8 m.)	15-20
18	Children (9 f. 9 m.)	10-15
29	Children (15 f. 14 m.)	5-10
35	Children (18 f. 17 m.)	0- 5
142		

* 4 additional men of original settlement group die at this time.

** 1 additional female of original settlement group dies at this time.

Appendix C

RECOMMENDED DAILY DIETARY ALLOWANCES
For Healthy Persons Living in the U.S.A.

These recommendations were worked out by a group of scientists of the Food and Nutrition Board of the National Research Council.

Family Members	Food Energy Calories	Protein Gm.	Calcium Gm.	Iron Mg.	Vitamin A I.U.	Thiamine mg.	Riboflavin mg.	Niacin mg.	Vitamin C mg.	Vitamin D I.U.
CHILDREN UP TO 12 YEARS:										
1-6 months (13 pounds)...	55/lb.	*	0.6	5	1500	0.4	0.5	6	30	400
7-12 months (20 pounds)..	45/lb.		0.8	7	1500	0.5	0.8	7	30	400
1-3 years (27 pounds)....	1300	40	1.0	7	2000	0.7	1.0	8	35	400
4-6 years (40 pounds)....	1700	50	1.0	8	2500	0.9	1.3	11	50	400
7-9 years (60 pounds)....	2100	60	1.0	10	3500	1.1	1.5	14	60	400
10-12 years (79 pounds)..	2500	70	1.2	12	4500	1.3	1.8	17	75	400
GIRLS:										
13-15 years (108 pounds).	2600	80	1.3	15	5000	1.3	2.0	17	80	400
16-19 years (120 pounds).	2400	75	1.3	15	5000	1.2	1.9	16	80	400
BOYS:										
13-15 years (108 pounds).	3100	85	1.4	15	5000	1.6	2.1	21	90	400
16-19 years (139 pounds).	3600	100	1.4	15	5000	1.8	2.5	25	100	400
WOMEN: (128 pounds, physically moderately active)										
25 years.................	2300	58	0.8	12	5000	1.2	1.5	17	70	...
45 years.................	2200	58	0.8	12	5000	1.1	1.5	17	70	...
65 years.................	1800	58	0.8	12	5000	1.0	1.5	17	70	...
Pregnant (second half)...	2600	78	1.5	15	6000	1.3	2.0	20	100	400
Lactating................	3300	98	2.0	15	8000	1.7	2.5	10	150	400

* No recommendations. (Intakes providing from 1.0 to 2.0 grams per pound bodyweight are common and adequate.)

Family Members	Food Energy Calories	Protein Gm.	Calcium Gm.	Iron Mg.	Vitamin A I.U.	Thiamine mg.	Riboflavin mg.	Niacin mg.	Vitamin C mg.	Vitamin D I.U.
MEN: (154 pounds, physically moderately active)										
25 years.................	3200	70	0.8	10	5000	1.6	1.8	21	75	...
45 years.................	3000	70	0.8	10	5000	1.5	1.8	20	75	...
65 years.................	2550	70	0.8	10	5000	1.3	1.8	18	75	...

(National Food and Nutrition Council's Recommended Daily Dietary Allowances 1961)

REFERENCES CITED

Anonymous
1967 ABC Calorie Counter Diet Guide. Fifth Edition. Stanford, Connecticut: Basic Health Publishers.
Baker, P.T. And F. Daniels, Jr.
1956 Relationship Between Skinfold Thickness and Body Cooling for Two Hours at 15° C. Journal of Applied Physiology 8: 409=415
Blumenstock, David I. and Saul Price
1967 Climates of the States: Hawaii. Environmental Science Data Service, Climatography of the United States 60-51. Washington, D.C.: U.S. Government Printing Office.
Braidwood, R.J.
1960 Levels in Prehistory: a Model for the Consideration of the Evidence. In Evolution After Darwin, Vol. II. Sol Tax, Ed. Chicago: University of Chicago Press.
Bryan, Edwin Horace
n.d. A Nature Trail at Hauula. The Mid Pacific.
1938 Fish and Fishing in Hawaii. Book 3. Honolulu: Castle and Cook Ltd.
Buck, Peter Henry
1964 Arts and Crafts of Hawaii. Section 1, Food. Reprint. Special Publication 45. Honolulu: B.P. Bishop Museum.
Buskirk, E.R., R.H. Thomson, and G.D. Whedon
1963 Metabolic Response to Cooling in the Human: Role of Body Composition and Particularly of Body Fat. In Temperature, Its Measurement and Control in Science and Industry. Vol. 3. J.D. Hardy, Ed. New York: Reinhold. pp. 429-442.
Cook, James
1967 The Journals of Captain James Cook on his Voyage of Discovery 1776-1780. J.C. Beaglehole, Ed. Cambridge: Hakluyt Society at the University Press. Extra Series 36.
Cordy, Ross H.
1974 Cultural Adaptation and Evolution in Hawaii: A Suggested New Sequence. Journal of the Polynesian Society 83: 180-191.
Dixon, George, Ed.
1968 A Voyage Around the World... in 1785, 1786, 1787. London: G. Goulding. Original Edition, 1788.
Edmondson, Charles Howard
1941 Viability of Coconut Seeds After Floating in Sea. Occasional Paper 16(12). Honolulu: B.P. Bishop Museum.
Ellis, William
1963 Narrative of a Tour of Hawaii...Journal of William Ellis. 3rd ed. Reprint of the London 1827 edition and the Hawaii 1927 edition. Honolulu: Advertiser Publishing Company, Ltd.
Emory, Kenneth Pike
1959 Origin of the Hawaiians. Journal of the Polynesian Society 68: 29-34.
1963 East Polynesian Relationships: Settlement Pattern and Time Involved as Indicated by Vocabulary Agreements. Journal of the Polynesian Society 72: 78-100.

Emory, Kenneth Pike, William J. Bonk, and Yosihiko H. Sinoto
1959 Fishhooks. Special Publication 47. Honolulu: B.P. Bishop Museum.
Emory, Kenneth Pike, and Yosihiko H. Sinoto
1964 Eastern Polynesian Burials at Maupiti. Journal of the Polynesian Society 73: 143-160.

______
1961 Facts About Food. Pittsburg, Pennsylvania: H.J. Heinz Co.
Finney, Ben Rudolph
1967 New Perspectives on Polynesian Voyaging. In Polynesian Culture History Essays in Honor of Kenneth P. Emory. G.A. Highland, et al., Eds. pp. 141-166. Special Publication 56. Honolulu: B.P. Bishop Museum.
Fosberg, F.R.
1948 Derivation of the Flora of the Hawaiian Islands. In Insects of Hawaii. Elwood C. Zimmerman. 1: 107-119. Honolulu: University of Hawaii Press.
Gladwin, Thomas
1970 East is a Big Bird. Cambridge, Massachusetts: Harvard University Press.
Golson, J., Ed.
1972 Polynesian Navigation. Polynesian Society Memoirs 34. Wellington, New Zealand: A.H. and A.W. Reed.
Griffin, P. Bion, et al.
1971 Archaeology of Halawa and Lapakahi: Windward Valley and Leeward Slope. New Zealand Archaeological Association Newsletter 14: 101-113.
Groube, L.M.
1967 Models in Prehistory: a Consideration of the New Zealand Evidence. Archaeology and Physical Anthropology in Oceania 2: 1-27.
Gutmanis, Jean
1975 Check List of Plants Introduced Into Hawaii by the Ancestors of the Hawaiians. Polynesian Voyaging Society Seminar Handout.
Handy, Edward Smith Craighill and Elizabeth Green Handy
1972 Native Planters in Old Hawaii. Bulletin 233. Honolulu: B.P. Bishop Museum.
Hawaii Water Authority
1959 Rainfall of the Hawaiian Islands.
Jarves, James Jackson
1847 History of the Hawaiian Islands. Third edition. Honolulu: Charles Edwin Hitchcock.
Kelly, Marion
1967 Some Problems with Early Descriptions of Hawaiian Culture. In Polynesian Culture History: Essays in Honor of Kenneth P. Emory. G.A. Highland, et al, Eds. Special Publication 56. Honolulu: B.P. Bishop Museum.
Kirch, Patrick Vinton
1970 The Halawa Valley Project. New Zealand Archaeological Association Newsletter 13: 23-26.
1971 Hālawa Dune Site (Hawaiian Islands): A Preliminary Report. Journal of the Polynesian Society 80: 228-236.
1973 Early Settlements and Initial Adaptational Modes in the Hawaiian Islands. A paper presented at the Annual Metting of the Society for American Archaeology, May 3, 1973, San Francisco.
1974 The Chronology of Early Hawaiian Settlement. Archaeology and Physical Anthropology in Oceania 9: 110-119.

Krauss, Beatrice
1972 Syllabus - Ethnobotany of Hawaii - 105. University of Hawaii.
Langworthy, C.F. and H.J. Deuel, Jr.
1972 Digestibility of Raw Rice, Arrowroot, Canna, Cassava, Taro, Tree-fern, and Potato Starches. The Journal of Biological Chemistry 52:251-261.
Le Blanc, J.
1954 Subcutaneous Fat and Skin Temperature. Canadian Journal of Biochemistry and Physiology 32: 354-363.
Levison, Michael, R.G. Ward and J.W. Webb
1973 The Settlement of Polynesia: A Computer Simulation. Minneapolis: University of Minnesota Press.
Lewis, David
1973 We, the Navigators: the Ancient Art of Land Finding in the Pacific. Honolulu: University Press of Hawaii.
Lethwaite, Gordon
1967 Geographical Knowledge of the Pacific Peoples. In The Pacific Basin... Herman R. Friis, Ed. Special Publication 38:57-353. New York: American Geographical Society.
Little, Michael A. and David H. Hochner
1973 Human Thermoregulation, Growth, and Mortality. An Addison-Wesley Module in Anthropology 36.
Maccaughey, Vaughn
1917 Food Plants of the Ancient Hawaiians. Scientific Monthly 4:75-80.
Malo, David
1971 Hawaiian Antiquities. Nathaniel B. Emerson, translator. 2nd edition. Special Publication 2. Honolulu: B.P. Bishop Museum.
Merrill, Elmer Drew
1943 Emergency Food Plants and Poisonous Plants of the Pacific. U.S. War Dept. Technical Manual 10-420. Washington, D.C.: U.S. Government Printing Office.
Miller, Carey Dunlap
1927 Food Values of Poi, Taro, and Limu. Bulletin 37. Honolulu: B.P. Bishop Museum.
1929 Food Values of Breadfruit, Taro Leaves, Coconut, and Sugar Canes. Bulletin 64. Honolulu: B.P. Bishop Museum.
1952 Taro as a Source of Thiamine, Riboflavin, and Niacin. Journal of the American Dietetic Association 28(5).
1974 The Influence of Food and Food Habits Upon the Stature and Teeth of the Ancient Hawaiians. In Early Hawaiians. Charles E. Snow. Lexington: University Press of Kentucky. pp. 167-175.
Miller, Carey Dunlap and Ruth C. Robbins
1940 Chemical Analysis and Vitamin Assays of Opihi, the Hawaiian Limpet. The Philippine Journal of Science 71: 1-14.
Miller, Carey Dunlap, et al.
1942 Vitamin Values of Hawaiian Grown Fruits and Vegetables. Hawaii Agricultural Experimentation Station Progress Notes 36.
1947 Vitamin Values of Foods in Hawaii. Hawaii Agricultural Experimentation Station Technical Bulletin 6.
1956 The Use of Pandanus Fruit as Food in Micronesia. Hawaii Agricultural Experimentation Station Technical Paper 333.
Miller, D.S. and J. Rivers
1972 Seasonal Variations in Food Intake in Two Ethiopian Villages. Proceedings of the Nutritional Society 31: 32A, 33A.

Morgan, Lewis Henry
1964 Ancient Society. Leslie A. White, Ed. Cambridge: Belknap Press of Harvard University Press.

———
1961 National Food and Nutrition Council's Recommended Daily Dietary Allowances. In Facts About Foods. Pittsburgh, Pennsylvania: H.J. Heinz Co.

Neal, Marie Catharine
1948 In Gardens of Hawaii. Special Publication 40. Honolulu: B.P. Bishop Museum.

Newman, T. Stell
1969 Cultural Adaptations to the Island of Hawaii Ecosystem: The Theory Behind the 1968 Lapakahi Project. In Archaeology on the Island of Hawaii. Richard Pearson, Ed. Asian and Pacific Archaeology Series 3. Honolulu: Social Science Research Institute, University of Hawaii.
1972 Man in the Prehistoric Hawaiian Ecosystem. In A Natural History of the Hawaiian Islands: Selected Readings. E. Alison Kay, Ed. Honolulu: University Press of Hawaii.

Pearson, Richard J., et al.
1971 An Early Prehistoric Site at Bellows Beach, Waimanalo, Oahu, Hawaiian Islands. Archaeology and Physical Anthropology in Oceania 6: 204-235.

Pope, William Thomas
1926 A Study of Certain Economic Fruit Plants of the Hawaiian Islands. PhD Dissertation, University of Hawaii.

Porter, David
1822 Journal of a Cruise Made to the Pacific Ocean...1812, 1813, 1814... 2 vols. 2nd ed. New York: Wiley and Halstead. pp. 54-55.

Potgieter, Martha and Carey D. Miller
1940 Hawaii's Food Requirements Under Normal and Emergency Conditions. Pan Pacific 4: 6-9.

Peinman, Fred M.
1967 Fishing: An Aspect of Oceanic Economy - An Archaeological Approach. Fieldiana: Anthropology. Fieldiana Museum of Natural History. Vol 56, no. 2.

Riley, Thomas J.
1973 Wet and Dry in a Hawaiian Valley: the Archaeology of an Agricultural System. PhD Dissertation, University of Hawaii.

Rock, Joseph F.
1974 The Indigenous Trees of the Hawaiian Islands. Rutland, Vermont: Charles E. Tuttle Co.

Sharp, Andrew
1956 Ancient Voyagers in the Pacific. Memoir 32. Wellington, New Zealand: Polynesian Society.

Sinoto, Yosihiko H.
1968 Position of the Marquesas Islands in East Polynesian Prehistory. In Prehistoric Culture in Oceania. I. Yawata and Y.H. Sinoto, Eds. Honolulu: Bernice P. Bishop Museum Press.

Suggs, Robert Carl
1960 The Island Civilizations of Polynesia. New York: The New American Library.

Taylor, Clarice Bromley
1969 Hawaiian Almanac. Sixth Edition. Honolulu: Tongg Publishing Co.,Ltd.

U.S. Weather Bureau
n.d. Climatic Summary of Hawaii Supplement, 1919-1952.
Van Dine, Delos Lewis
1904 Mosquitos in Hawaii. Hawaii Agricultural Experimentation Station Bulletin 6.
Wilson, James
1799 A Missionary Voyage to the Southern Pacific Ocean, Performed in the Years 1796, 1797, 1798, in the Ship Duff... London: T. Chapman.
Zimmerman, Elwood C.
1963 Nature of the Land Biota. In Man's Place in the Island Ecosystem. F.R. Fosberg, Ed. Honolulu: Bishop Museum Press.

PRIVATE INTERVIEWS

Farnsworth, Letitia
1975 Private interview, October 21. Home Economics Department, Gasco Inc., Honolulu.
Finney, Ben Rudolph
1975 Private interviews October/November. Professor of Anthropology, University of Hawaii. Honolulu.
Gutmanis, Jean
1975 Private interview, October 14, 15.
Hall, Reiko
1975 Private interview, October 22. Ahuimanu Pet Clinic.
Hanna, Joel
1975 Private interview, Associate Professor of Physiology and Anthropology, University of Hawaii.
Kirch, Patrick Vinton
1975 Private interview, October 22. Department of Anthropology, Bernice P. Bishop Museum, Honolulu.
Marsden, Gene
1975 Private interview. Thirty year resident of Hauula, Hawaii.
Preston, Mrs. George
1975 Private interview. Fifty year resident of Hauula.
Schattenberg, Pat
1975 Private interview, October. Graduate Student, University of Hawaii, Honolulu.
Tabrah, Frank
1975 Private interview, October 17, November 18. Professor of Community Health, University of Hawaii, Honolulu.
Tuggle, David H.
1975 Private interview, October and November. Associate Professor of Anthropology. University of Hawaii, Honolulu.